Program Curriculum and Teaching-Learning Processes
Curricular Gaps have been identified arbitrarily

Action:

Each course coordinator asked to identify the curriculum gaps and instructed to plan and conduct the activities to bridge the gaps. Meetings at department level have been conducted

Outcome:

The curricular gaps are identified and attained POs and PSOs.

Each semester we have identified 2 curricular gaps and conducted the activities as per academic calendar.

Course Outcomes – III Semester **Year of Study: 2016-17**
Course Name: Basic Thermodynamics (15ME33) **Course Code: C203**

At the end of the course the student should be able to:

C203.1	Explain the Thermodynamic systems, properties, Zeroth Law of Thermodynamics, temperature scales and energy interactions.
C203.2	Determine heat, work, internal energy, enthalpy for flow and non-flow process using First and Second Law of Thermodynamics.
C203.3	Interpret the behavior of pure substances and its applications to practical problems.
C203.4	Determine change in internal energy, change in enthalpy and change in entropy using TD relations for ideal gases.

Correlation matrix

CO	PO1	PO2	PO3	PO4	PO5	PO6	PO7	PO8	PO9	PO10	PO11	PO12	PSO1	PSO2
C203.1	3	2	2	2	-	-	-	-	-	-	-	2	3	1
C203.2	2	3	2	2	-	-	-	-	-	1	-	2	3	1
C203.3	3	2	3	2	-	-	-	-	-	-	-	2	3	1
C203.4	3	2	1	2	-	-	-	-	-	1	-	1	3	1
C203	3	2	2	2	-	-	-	-	-	1	-	2	3	1

Course code: Basic Thermodynamics

Course code: 15ME33

Curricular Gap: Application of entropy and phase change concepts in pure substances.

Technical Quiz on Thermal Engineering

1) Thermal efficiency of S.I. engines is low, due to ____

a. low compression ratio
b. high compressionratio
c. equal to 1
d. None of these

Answer: low compression ratio

2) What is the partial volume of a gas in a mixture?

a. Volume occupied by a single gas alone of a mixture at the same temperature and pressure of the mixture
b. Total volume of the mixture at a certain pressure and temperature divided number of gases mixed in the mixture
c. Both a. and b.
d. none of the above

Answer: volume occupied by a single gas alone of a mixture at the same temperature and pressure of the mixture

3) What is the degree of subcooling?

a. The difference between saturation temperature of liquid and actual temperature of liquid
b. The difference between saturation temperature of vapour and actual temperature of liquid
c. The difference between saturation temperature of liquid and actual temperature of vapour
d. The difference between saturation temperature of vapour and actual temperature of vapour

Answer: the difference between saturation temperature of liquid and actual temperature of liquid

4) PMM2 is the machine which violates ___________

a. Kelvin-Planck statement
b. Clausius statement
c. both a. and b.
d. none of the above

Answer: both a. and b.

5) What is the entropy of the system at equilibrium state?

a. Zero
b. Minimum
c. maximum

Technical Quiz on Thermal Engineering

Questions **Responses** 770

Total points: 20

770 responses

Not accepting responses

Message for respondents

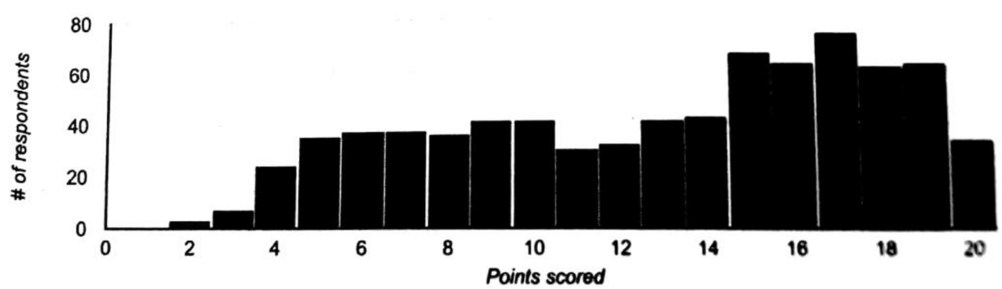
This exam is not currently accepting submissions. Please check back again later.

Summary | Question | **Individual**

Insights

Average	Median	Range
12.94 / 20 points	14 / 20 points	2 - 20 points

Total points distribution



2.1.2 Mapping with POs and PSOs only possible with proper identification of curricular gaps

Action:

Each course coordinators have communicated the content beyond the syllabus at department level.

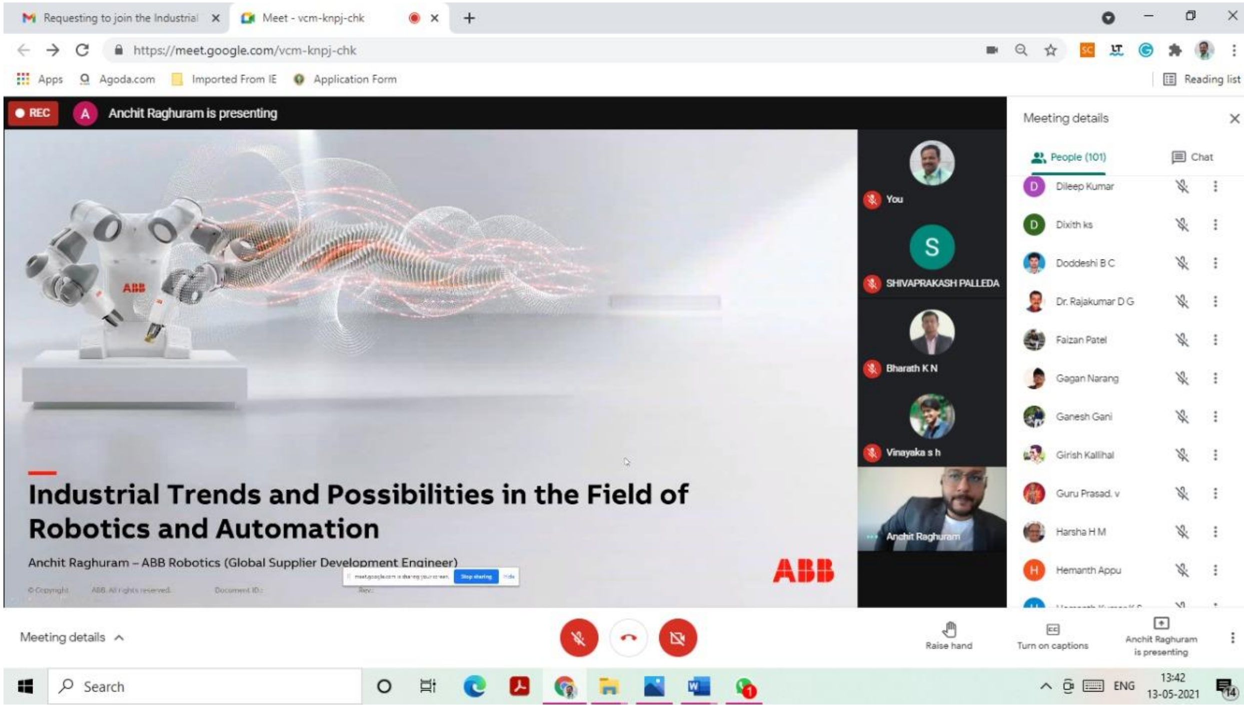
To Bridge the gap course coordinators are conducting activities and feedback is taken.

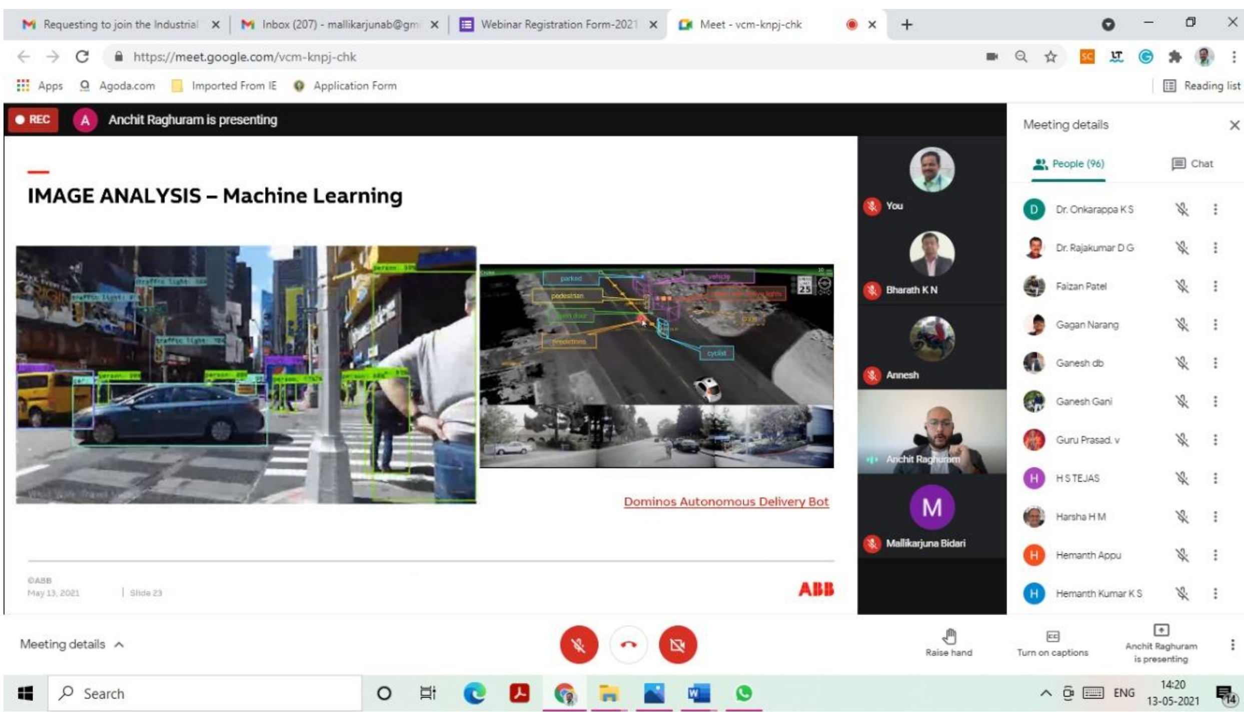
Outcome:

Impact analysis is made based on feedback from students to attain POs and PSOs. The gaps are communicated and these gaps bridged by conducting activities.

<u>Content beyond the Syllabus</u>

Curricular Gap: Industrial Trends and Possibilities in the field of Robotics and Automation


Anchit Raghuram is presenting
Industrial Trends and Possibilities in the Field of Robotics and Automation
Anchit Raghuram – ABB Robotics (Global Supplier Development Engineer)
ABB
Meeting details
People (101)
13:42
13-05-2021


Anchit Raghuram is presenting
IMAGE ANALYSIS – Machine Learning
Dominos Autonomous Delivery Bot
ABB
Meeting details
People (96)
14:20
13-05-2021

Impact analysis based on Feedback questions

1. **Whether the content of the topic relevant to the academics?**

2. **Did the presentation reveal the current trend in the industry?**

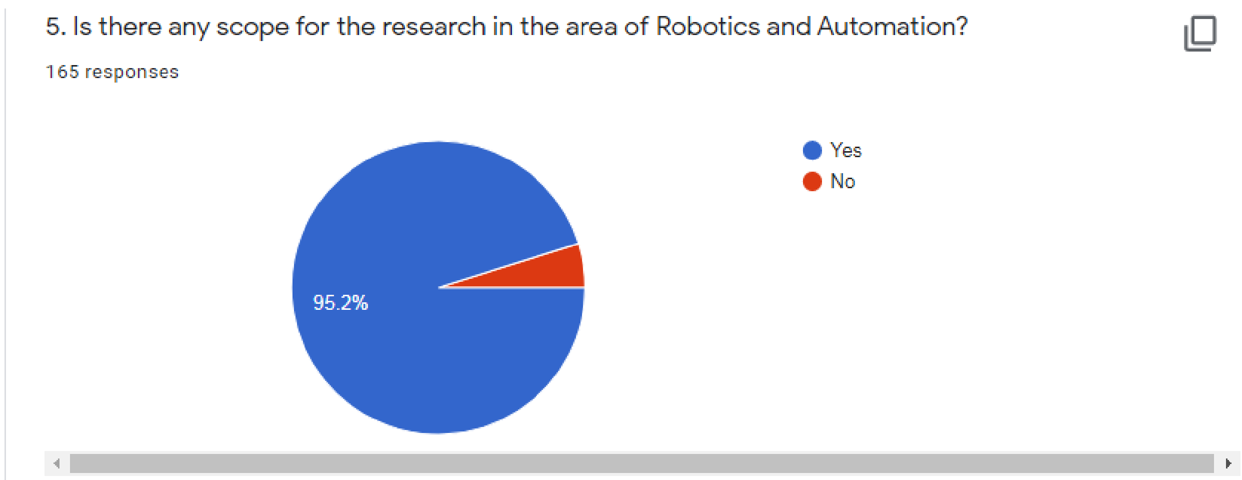
3. **Did the presentation serving the purpose which is intended do?**

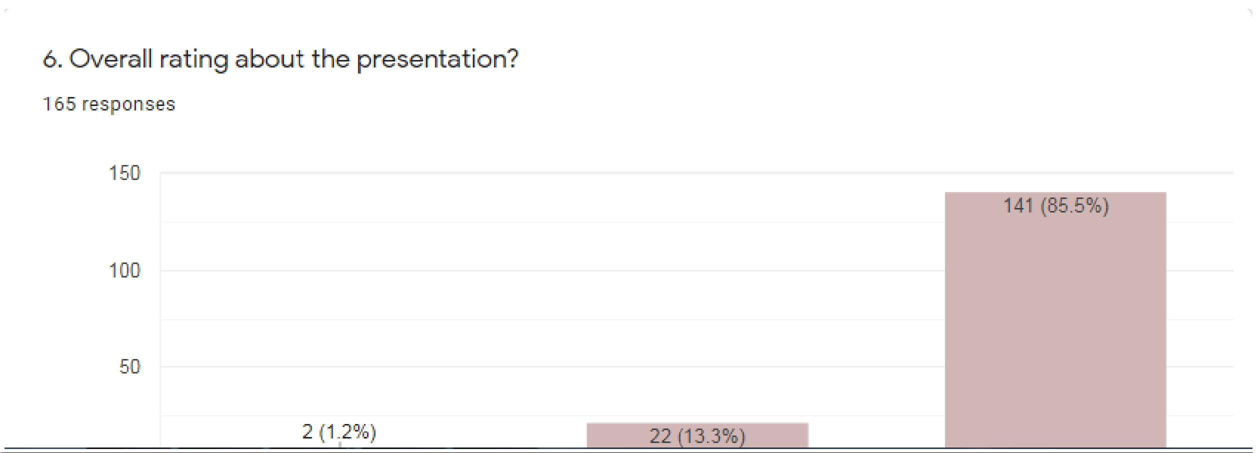
4. **Whether the speaker has got strong control over subject?**

5. **Is there any scope for the research in the area of Robotics and Automation?**

6. **Overall rating about the presentation?**

7. **Any suggestions for the improvement**





2.2.1 Teaching aids and Continuous evaluation system is not implemented adequately

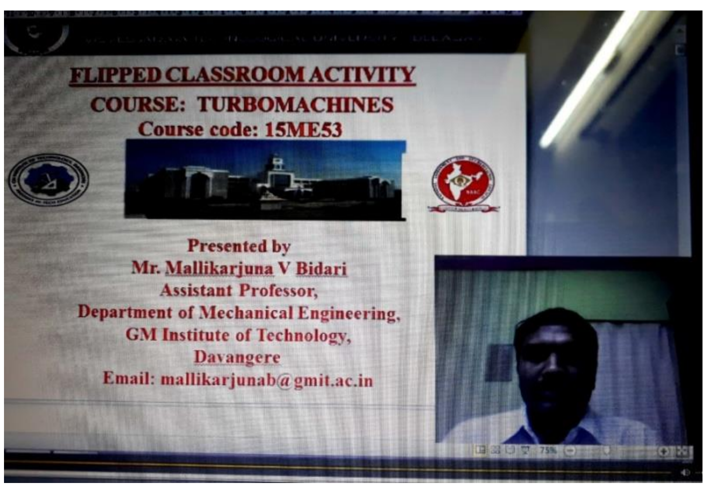
Action: Corrective measures have taken by HOD and Academic dean with respect to adopting modern tools usage and Continuous evaluation system.

Outcome:

Continuous evaluation process is implemented effectively and monitored at the end of each semester.

Proof for teaching aids: **NPTEL links:** https://swayam.gov.in/NPTEL

Entrepreneurship Development Programme on from 27/02/2020 to 28/02/2020



ICT enabled learning -Flipped Class Room Activity on Turbo machines Course for 5th semester students from 25/12/2018 to 29/12/2018 (https://youtu.be/1FC-xvyQDtU, https://youtu.be/JH3s8Byi3-M, https://youtu.be/s_2HkcBl2UQ)

Continuous evaluation process:

Course: Fluid Mechanics and Machines Lab

Course code: 18MEL57

Proof :

10

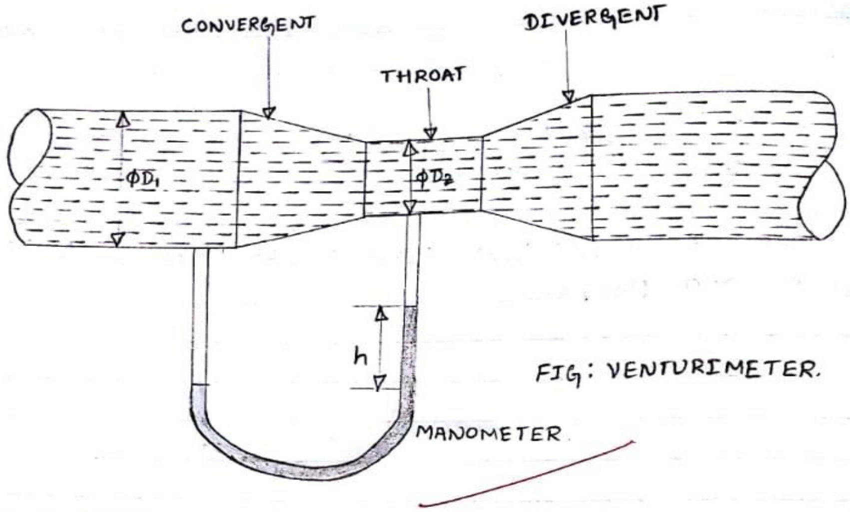


FIG: VENTURIMETER.

OBSERVATION:

* Area of measuring tank 'A' = 0.125 m^2.
* Acceleration due to gravity 'g' = 9.81 m/sec^2.
* Diameter of inlet pipe of venturimeter 'd_1' = 25 mm.
* Diameter of inlet throat 'd_2' = 12.5 mm.
* Rate of Rise of water in collecting tank R = 100 MM.

TABULAR COLUMN:

S.I No	Rise of water 'R' in mm.	Time taken 'T' sec	Differential head 'h' mm of kg	Head of water (H) meters.	Actual discharge. Q_{act} in m^3/sec	Theoretical discharge. Q_{the} in m^3/sec	Co-efficient of discharge 'cd'	Average
1.	100	30	56	0.7056	4×10^{-4}	4.71×10^{-4}	0.84	
2.	100	21	106	1.3356	5.71×10^{-4}	6.488×10^{-4}	0.88	0.863
3.	100	15	210	2.646	8×10^{-4}	9.132×10^{-4}	0.87	

RUBRICS OF EVALUATION.

Expt conduction (10M)	Observation (10M)	viva (5M)	Practical Record (5M)	Total Marks (30M)
10	10	3	5	28

RESULT :-

Co-efficient of discharge of water Venturimeter

Cd = 0.863.

Seen

28/1/21

Sl NO.	Name of experiment	Marks obtained (30)	IA (10)	Total (40)
1.	Venturimeter.	28		
2.	Orifice meter.	29		
3.	Calibration of notches	29		
[illegible]	[illegible]			
4.	Performance test on Pelton wheel.	29		
5.	Performance test on single state Centrifugal pump.	29		
6.	Performance test on Reciprocating pump.	29		
		Avg 29	09	38.

27/1/21.

2.2.2 Internal question papers need a greater attention. Quality of question papers and assignment evaluation is not up to the mark.

Action:

DQAC has taken some steps to improve the quality of internal question paper by using appropriate cognitive levels Bloom's Taxonomy. Course coordinators are informed to set internal question papers and assignments as per COs

Outcome:

Improved the performance of the students. Scheme and Rubrics are developed to meet COs.

Proof: QP Sample

USN

Srishyla Educational Trust®, Bheemasamudra
GM INSTITUTE OF TECHNOLOGY, DAVANGERE
DEPARTMENT OF MECHANICAL ENGINEERING

with B++ Grade

FIRST INTERNAL ASSESSMENT QMP 7.5 R/C – 5 REV.0

Semester	5th	Section	A & B
Subject	Turbomachines	Subject Code	18ME54
Date	23-10-2020	Time	4 PM to 5 PM
AY	2020-21 (Odd Semester)	Max. Marks	30

Note: Answer any *Five* of the following

Q. No.	QUESTIONS	Marks	CO	Level	PO
	Module 1 and 2				
1	*Define* turbomachine. *List* the principal components of turbomachine?	06	1	L_1	2
2	*Define* specific speed of a pump and turbine. *Derive* an expression for the specific speed of pump in terms of discharge, speed, and head	06	1	L_1,L_3	2
3	*What* are Unit quantities? *Obtain* an expression for the same in terms of Head. (i) Unit Flow (ii) Unit Speed (iii) Unit Power.	06	1	L_1,L_3	2
4	Tests on a turbine runner 1.25 m in diameter at 30 m head gave the following results: Power developed= 736 KW, Speed= 180 rpm, Discharge = 2.7 m^3/sec. *Find* the diameter, speed and discharge of a runner to operate at 45m head and give 1472 KW at the same efficiency. *What* is the specific speed of both turbines	06	1	L_1	1,2
5	Two geometrically similar pumps are running at the same speed of 1000 RPM. One pump has an impeller diameter of 0.3 m and lift the water at rate of 20 LPS against a head of 15 m. *Determine* the head and impeller diameter of other pump to deliver half of the discharge.	06	1	L_3	1,2
6	With usual notations and velocity triangles *Derive* alternate turbine equation and identify the components of energy transfer.	06	2	L_3	1,2
7	*Define* the Utilization factor (Ɛ) and write the expression. *Derive* the relation between Degree of reaction and Utilization factor.	06	2	L_1, L_3	1,2
8	*Obtain* the expression for maximum utilization factor in 50% reaction turbine	06	2	L_3	1

Proof: Assignment Rubrics

Parameters	Marks	Low	Medium	High
Assignment 1	10	Student was able to answer 6 questions out of 12 questions	Student was able to answer only 8-10 questions out of 12 questions	Student was able to answer all questions (12 out of 12)
		6-7 Marks	8-9 Marks	10 Marks
Assignment 2	10	Student was able to answer 6 questions out of 12 questions	Student was able to answer only 8-10 questions out of 12 questions	Student was able to answer all questions (12 out of 12)
		6-7 Marks	8-9 Marks	10 Marks
Assignment 3	10	Student was able to answer 6 questions out of 12 questions	Student was able to answer only 8-10 questions out of 12 questions	Student was able to answer all questions (12 out of 12)
		6-7 Marks	8-9 Marks	10 Marks
Average of all three assignments to meet COs		(Assign1+ Assign2+ Assign3)/3		

2.2.4 Impact analysis of 1-1 interaction is not illustrated

Action:

Industry interaction is needed.

A format has to be designed by the IIC coordinator for the impact analysis.

Action Taken:

MoU signed.

Table: Industry supported Laboratory details

Sl. No.	Name of industry supported Laboratories	Area of collaboration (Student learning)
1.	Smart Engineers, Peenya Industrial Estate, Bengaluru	Product development and research on CNC Machining Process
2.	GM Sugars and Energy Limited, Sanguru	Process of Sugar production and Power Generation

Table: Details of MoUs

Sl. No.	Name of Company	Area of collaboration (Student learning)
1.	Grasim Industries Limited, Harihar	Training and Internships
2.	GM Sugars and Energy Limited, Sangur, Haveri	Training and Industrial Visit
3.	Aradhya Steels Pvt. Limited, Davangere	Expert talk and Industrial Visit
4.	Cargill India Pvt.Limited, Harihar	Training and Industrial Visit
5.	CADD Centre, Davangere	Training, workshops and Intercollege Quiz competition
6	Vidvath Technologies Pvt. Ltd., Davangere	Training, Internship, Expert Talk
7	Nandi Enterprises, Davangere	Industry Visit, Training, Internship
8	Medini Auto Desk, Vijayanagar, Bengaluru	Training on CAD, Certification Courses, 3D Printing, Auto Desk Inventor

2.2.5 Impact analysis of industrial and summer training is not illustrated.

Action:

For 2015 and 2018 schemes, VTU has made mandatory for all the students to undergo internship program. Now all the students should undergo the internship program. After completion of intern ship the feedback from the students and industry persons are taken.

Outcome:

Impact analysis made based on Feedback taken from students.

Proof: Industrial Visit and Summer Training

Impact Parameters on High (Red), Medium (Green) and Low (Purple) scale:

Sl. No.	Questions
1	Your Experience at the Industrial visit
2	Is it helped to gain the knowledge related to the subject?
3	Industrial visit was as per your expectations
4	Was the Industrial visit educational?
5	Were you satisfied about service you received in the Industrial visit?
6	How would you rate your overall experience of the Industrial visit?

Industry : 1. Varahi Hydro Power Plant, Hosangadi, Karnataka

2. Kaiga Nuclear Power Station, Kaiga, Karnataka

Semester : Vth A & B Sec

Date of visit : 2nd and 3rd November 2018

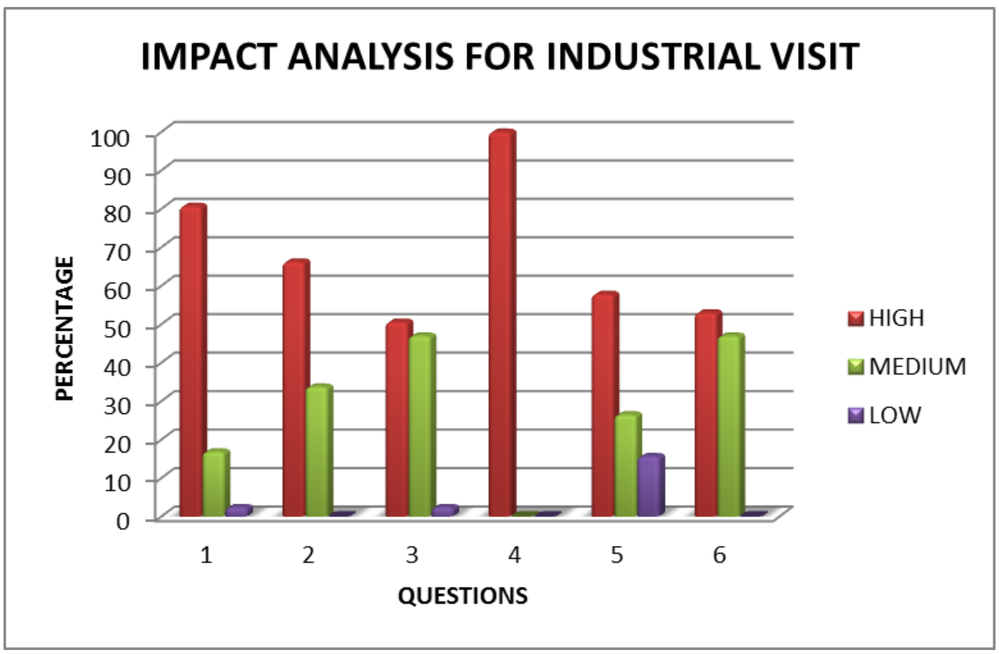


Figure: Impact analysis for Industrial Visit 2018-19

Illustration: Gain of Practical exposure on turbines and to understand the current industry technologies. Concern about energy, environment and societal benefits.

➢ Impact analysis for Internship

Impact Parameters on Strongly Agree (Blue)-3, Agree (Red)-2 and Disagree (Purple)-1 scale:

Sl. No.	Questions
1	Whether the Internship achieved the Program Outcomes (PO's)?
2	Whether the Internship achieved the Specific Program Outcomes?
3	Whether the internship helps you to decide your specific career development direction?
4	Whether the internship helped you to improve your communication skill effectively?
5	On a scale of 1 to 3 how would you rate your internship?

Industry : Bosch Limited, Bengaluru, Karnataka

Semester : VIIth A Sec

Date of visit : 9th July to 9th August 2018

The impact analysis of internship is shown in below Figure

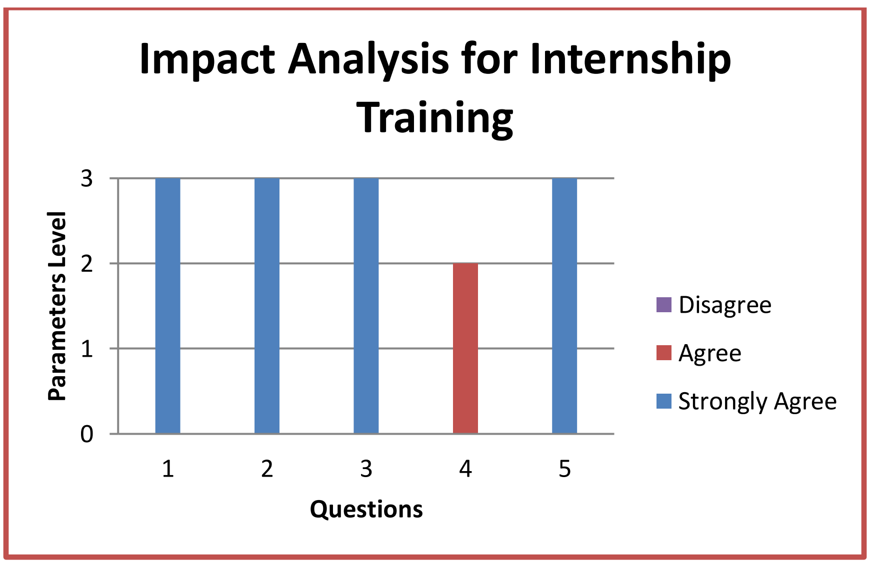


Figure : Impact analysis for Internship 2018-19

Illustration: Gain of Practical exposure to understand the current industry requirements. Requirement of energy and human values to meet industrial needs. The sustainable growth leads to achieve global standards.

INSTITUTE VISION AND MISSION

Vision:

"To develop technologically competent, socially responsible and humane engineers and managers to meet the ever growing challenges of the Global Environment"

Mission :

1. To provide quality technical and management education by applying best practices in teaching, learning and with the state of the art infrastructural facilities.
2. To mould engineers and managers with appropriate pedagogy to develop leadership qualities and skills by imbibing professional ethics to make them industry ready.
3. To develop a student-centric institution which evolves and fosters the talents of budding engineers, managers and entrepreneurs and prepare them to make a positive contribution to the society.
4. To promote Research and Consultancy through collaboration with industries and Government Organisations.

DEPARTMENT VISION AND MISSION

Vision:

To develop competent Mechanical engineers to work in an interdisciplinary environment with innovation and professional ethics to serve the needs of society.

Mission:

1. Imparting quality education to students to excel in Mechanical Engineering.
2. To prepare technocrats with professional skills to meet industrial needs and for higher education.
3. To develop ethically and socially responsible engineers capable to solve real time problems.

PROGRAM EDUCATIONAL OBJECTIVES (PEOs)

PEO 1: KNOWLEDGE

To prepare students with overall knowledge in Mechanical Engineering and enabling them to understand specific problem areas and finding optimum solutions for the same.

PEO2: SKILL

To train the students on emerging trends of technology with required technical skills to meet industrial needs and encourage to pursue higher education, research and spirit of entrepreneurship.

PEO3: ATTITUDE

To mould the engineers with required professional ethics and values, to serve the society at large.

PROGRAM SPECIFIC OUTCOMES (PSOs)

1. Graduates of Mechanical engineering are capable to use technical skills to pursue research and higher education in the field of advanced materials and sustainable energy sources.
2. Graduates of Mechanical engineering will demonstrate skills in design and development of Mechanical systems and processes.

PROGRAM OUTCOMES (POs)

Engineering Graduates will be able to:

1. **Engineering knowledge:** Apply the knowledge of mathematics, science, engineering fundamentals, and an engineering specialization to the solution of complex engineering problems.
2. **Problem analysis:** Identify, formulate, review research literature, and analyze complex engineering problems reaching substantiated conclusions using first principles of mathematics, natural sciences, and engineering sciences.
3. **Design/development of solutions:** Design solutions for complex engineering problems and design system components or processes that meet the specified needs with appropriate consideration for the public health and safety, and the cultural, societal, and environmental considerations.
4. **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.
5. **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.
6. **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.

7. **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.
8. **Ethics:** Apply ethical principles and commit to professional ethics and responsibilities and norms of the engineering practice.
9. **Individual and team work**: Function effectively as an individual, and as a member or leader in diverse teams, and in multidisciplinary settings.
10. **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.
11. **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.
12. **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.

LESSON PLAN DETAILS:-

Semester:- Fifth (CBCS Scheme) **Academic Year:-** 2021-22

Department:- Mechanical Engineering	**Course Type:- Core**
Course Title:- Turbomachines	**Course Code:- 18ME54**
L-T-P:- 3- 1 - 0	**Teaching hours per week/Credits:- 04**
Total Contact Hours:- 50, Credits - 03	**Exam Hours:- 03**
SEE Marks:- 60	**CIE Marks:- 40**
Course Coordinators:- Dr. Rajakumar D.G. and Mr. Mallikarjuna V. Bidari	**Section:- "A & B"**

Course Learning Objectives:

- Understand typical design of Turbo machine, their working principle, application and thermodynamics process involved.
- Study the conversion of fluid energy to mechanical energy in Turbo machine with utilization factor and degree of reaction.
- Analyse various designs of steam turbine and their working principle.
- Study the various designs of hydraulic turbine based on the working principle.
- Understand the various aspects in design of power absorbing machine.

MODULE 1

Introduction: Definition of turbo machine, parts of turbo machines, Comparison with positive displacement machines, Classification, Dimensionless parameters and their significance, Unit and specific quantities, model studies and its numerical. (Note: Since dimensional analysis is covered in Fluid Mechanics subject, questions on dimensional analysis may not be given. However, dimensional parameters and model studies may be given more weightage.)

Thermodynamics of fluid flow: Application of first and second law of thermodynamics to turbo machines, Efficiencies of turbo machines, Static and Stagnation states, overall isentropic efficiency, stage efficiency (their comparison) and Polytropic efficiency for both compression and expansion processes. Reheat factor for expansion process. Simple Numerical on stage efficiency and Polytropic efficiency. **(10 Hours)**

MODULE 2

Energy exchange in Turbo machines: Euler's turbine equation, Alternate form of Euler's turbine equation, Velocity triangles for different values of degree of reaction, Components of energy transfer, Degree of Reaction, utilization factor, Relation between degree of reaction and Utilization factor, Problems.

General Analysis of Turbo machines: Radial flow compressors and pumps – general analysis, Expression for degree of reaction, velocity triangles, Effect of blade discharge angle on energy transfer and degree of reaction, Effect of blade discharge angle on performance, , General analysis of axial flow pumps and compressors, degree of reaction, velocity triangles, Numerical Problems

(10 Hours)

MODULE 3

Steam Turbines: Classification, Single stage impulse turbine, condition for maximum blade efficiency, stage efficiency, Need and methods of compounding, Multi-stage impulse turbine, expression for maximum utilization factor, Numerical Problems.

Reaction turbine – Parson's turbine, condition for maximum utilization factor, reaction staging. Numerical. **(10 Hours)**

MODULE 4

Hydraulic Turbines: Classification, various efficiencies. Pelton Wheel – Principle of working, velocity triangles, design parameters, maximum efficiency, and numerical problems.

Francis turbine – Principle of working, velocity triangles, design parameters, and numerical problems Kaplan and Propeller turbines - Principle of working, velocity triangles, design parameters and Numerical Problems. Theory and types of Draft tubes. **(10 Hours)**

MODULE 5

Centrifugal Pumps: Classification and parts of centrifugal pump, different heads and efficiencies of centrifugal pump, Theoretical head – capacity relationship, Minimum speed for starting the flow, Maximum suction lift, Net positive suction head, Cavitation, Need for priming, Pumps in series and parallel. Problems.

Centrifugal Compressors: Stage velocity triangles, slip factor, power input factor, Stage work, Pressure developed, stage efficiency and surging and problems. **(10 Hours)**

TEXT BOOKS:

1. An Introduction to Energy Conversion, Volume III, Turbo machinery, V. Kadambi and Manohar Prasad, New Age International Publishers, reprint 2008.**[T1]**
2. Turbines, Compressors & Fans, S. M. Yahya, Tata McGraw Hill Co. Ltd., 2nd edition, 2002 **[T2]**
3. Turbomachines, B. U. Pai , Wiley First Edition 2013.

REFERENCE BOOKS:

1. Principals of Turbo machines, D. G. Shepherd, The Macmillan Company (1964). [**R1]**
2. Fluid Mechanics & Thermodynamics of Turbo machines, S. L. Dixon, Elsevier (2005). **[R2]**
3. Text Book of Turbo machines, M. S. Govindegouda and A. M. Nagaraj, M. M. Publications, 4Th Ed, 2008. **[R3]**
4. Turbo machine, B.K.Venkanna PHI, New Delhi 2009. **[R4]**

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

CO1: Understand model studies and thermodynamic analysis of turbomachines [L1].

CO2: Analyse the energy transfer in Turbo machine with degree of reaction and utilisation factor [L4]

CO3: Classify, analyse and understand various type of steam turbine [L2, 4].

CO4: Classify, analyse and understand various type of hydraulic turbine [L2, 4].

CO5: Understand the concept of radial power absorbing machine and the problems involved during its operation [L1,3].

Prerequisites: The prerequisite courses that students should have the knowledge of Mathematics, Thermodynamics and Fluid Mechanics.

Course Overview: Turbo machines are basically rotodynamic machines which work on the principles of dynamic action. This course deals with the definition of a turbo machines, main parts, classification and its comparison with positive displacement machines. The first and second laws of thermodynamics, adiabatic efficiency, drawing of velocity triangles diagram, dimensionless parameters are the common factors for the calculation of power of the turbo machines.

The chapter on energy transfer in turbomachine gives an Euler equation which further helps in the analysis of a turbomachine. The general analysis helps in classifying turbomachines. The thermodynamics of fluid flow and thermodynamic analysis of compression and expansion processes help in the study of power absorbing and power producing turbomachines. After studying the common features and analysis of turbomachines and to indicate that once the principles are learned, essentially the same procedures may be applied with slight differences in emphasis depending on the types of turbomachines such as configured compressors, axial flow compressor, centrifugal pumps, steam turbines, and hydraulic turbines.

Relevance of the course: Power is one of the main needs for the development of any country. At present all the power plants generate electricity using either hydraulic, steam or gas turbines. Most of the industries use power absorbing turbomachines such as fans, compressors, and blowers. Therefore, it is very much essential for mechanical engineering students to study the principles of turbomachines.

Students should study Part-A in general to know the fundamental principles of turbomachines then Part-B in particular to know the construction, working and analysis of turbomachines

Application Areas:

- Steam turbines are used in thermal power plants and atomic power plants to run the generator and generate electricity, which is supplied to the prospective customers through a long transmission lines.
- Hydraulic turbines are used in hydro electric power plants to generate electricity.
- Gas turbines are used in power plants as well as in aviation industries.
- Fans and blowers are used in industries for various applications.
- Compressors are used in gas turbines, vapor compression refrigeration systems, automobiles, pneumatic systems etc.

MODULE WISE LESSON PLAN

MODULE-1 : INTRODUCTION & THERMODYNAMICS OF FLUID FLOW	Planned hours: 10
Learning objectives: At the end of this Module student should be able to:	
• Define Turbomachine & Identify the main parts of turbo machines, Classify turbo machines. and compare it with positive displacement machines • Discuss the effect of Reynolds number, specific speed & dimensionless parameters and their physical significance on turbo machines • Explain Compression process – Overall isentropic efficiency of compression; Stage efficiency, Polytropic efficiency and preheat factor • Explain Expansion process – Overall isentropic efficiency of compression; Stage efficiency, Polytropic efficiency and preheat factor	

Lecture No.	Topics covered	Teaching Method	POs attained	COs attained	Text/Reference Book/Chapter No.
L1	Introduction to the subject, Definition of a Turbomachine, parts of turbomachines.	Chalk & Board Video Animation	1,2	1,2	T1/1,R3/1,R4/1

L2	Comparison with positive displacement machines, Classification, Application of first and second law's of thermodynamics to turbomachines, efficiencies.	Chalk & Board		1,2	T1/1,R3/1,R4/1
L3	Application of first and second law's of thermodynamics to turbomachines, efficiencies, dimensionless parameters and their physical significance,	Chalk & Board		1,2	T1/1,R3/1,R4/1
L4	Dimensionless parameters and their physical significance Effect of Reynolds's number, specific speed,	Chalk & Board		1,2	T1/1,R3/1,R4/1
T1	Illustrative examples on model studies.	Chalk & Board		1,2	T1/1,R3/1,R4/1
T2	Numerical	Chalk & Board		1,2	T1/1,R3/1,R4/1
L5	Static and Stagnation states, Incompressible fluids and perfect gases,	Chalk & Board		1,2	R3/3,R4/3
L6	overall isentropic efficiency, Stage efficiency (their comparison);	Chalk & Board		1,2	R3/3,R4/3
L7	Polytropic efficiency for both Comparison and expansion process Reheat factor for expansion process	Chalk & Board Chalk & Board		1,2	R3/3,R4/3
L8	Numericals	Chalk & Board		1,2	R3/3,R4/3
T3	Numericals	Chalk & Board		1,2	R3/3,R4/3
T4	Numericals	Chalk & Board		1,2	R3/3,R4/3

Exercise:

Exercise	COs attained
1. Define Turbo machine with a neat sketch explain the main parts of turbomachines and give classification of turbo machines.	
2.Compare Positive displacement machines with Turbo machines or Rotary machines or Dynamic machines.	
3. Give the significance of the following non dimensional parameters i) discharge co-efficient ii) head or pressure or energy co-efficient (iii) Power co- efficient (iv) Reynolds number v) specific speed and write its expressions for pump and turbines	

4. A quarter-scale turbine model is tested under a head of 10m. The full scale turbine is required to work under a head of 28.5 m and 415 rpm. (a) At what speed must the model be run if it develops 94kW and uses 0.96 m^3/s at this speed? (b) What power will be obtained from the full-scale turbine? (c) Name of the type of turbine.	1,2
5.A Francis turbine is built to scale of 1:5. Model Data P=4 kW, N = 350 rpm, H = 2 m Prototype Data P = ? N = ? H = 6m	
6. What is compression process? Derive and expression for overall isentropic efficiency of compression.	1,2
7.Derive an expression for (i) total to total efficiency (ii) total to stagnation efficiency (iii) stagnation to total efficiency and stagnation to stagnation efficiency of compression process.	
8. Explain stage efficiency. Derive its expression and write its relation with overall isentropic efficiency of compression.	
9. Describe polytrophic efficiency. Derive its expression and write its relation with overall isentropic efficiency for different pressure ratio.	
10. What is expansion process? Derive an expression for overall isentropic efficiency of expansion.	
11. Derive an expression for (i) total to total efficiency (ii) total to stagnation efficiency (iii) Stagnation to total efficiency and (iv) Stagnation to stagnation efficiency of expansion process.	
12. Explain stage efficiency. Derive its expression and write its relation with overall isentropic efficiency of expansion.	
13. Describe polytrophic efficiency. Derive its expression and graphically represents its relation with overall isentropic efficiency for different expansion ratio.	
14. Air at STP and at 14 m/s is accelerated isentropically in a nozzle to 225 m/s. Find (a) the change in temperature (b) the change in pressure (c) the change in density (d) the change in stagnation pressure and (e) the change in stagnation temperature.	
15.An air compressor has the following data: Inlet pressure 1.02 bar, Exit pressure = 1.5 bar, Inlet temperature=300 K, Exit temperature = 340 K. Calculate (a) the isentropic compression efficiency and (b) the Polytropic efficiency	
16. A turbine has four stages and each stage pressure ratio is 2. The inlet static temperature is 630^0c. The mass flow rate is 30 kg/s. The overall efficiency is 0.8. Calculate (a) the Polytropic efficiency, (b) the stage efficiency, (c) the power developed, and (d) the reheat factor.	

MODULE-2: **ENERGY EXCHANGE & GENERAL ANALYSIS OF TURBOMACHINES**	**Planned hours: 10**

Learning objectives: At the end of this Module student should be able to:

- Derive the Euler's turbine equation and explain the significance of components of energy transfer.
- Define and discuss the significance of degree of reaction & derive an expression between utilization factor and degree of reaction.
- Learn how to draw velocity triangles diagram for axial flow compressors and pumps for different values of degree of reaction.
- Explain the general analysis of a turbo machine – effect of blade discharge angle on energy transfer and degree of reaction.
- Discuss the General analysis of axial and radial flow turbines.

Lecture No.	Topics covered	Teaching Method	POs attained	COs attained	Reference Book/Chapter No.

L9	Euler's turbine equation, Alternate form of Euler's turbine equation, Components of energy transfer,	Chalk & Board	1,2,12	3,4,5	T1/2,R1/3, R3/2,R4/2
L10	velocity triangles for different values of degree of reaction,	Chalk & Board		3,4,5	T1/2,R1/3, R3/2,R4/2
L11	Components of energy transfer, Degree of Reaction	Chalk & Board		3,4,5	T1/2,R1/3, R3/2,R4/2
L12	Degree of Reaction	Chalk & Board		3,4,5	T1/2,R1/3, R3/2,R4/2
T5	Utilization factor , relation between utilization factor and degree of reaction,	Chalk & Board		3,4,5	T1/2,R1/3, R3/2,R4/2
T6	Numerical	Chalk & Board		3,4,5	T1/2,R1/3, R3/2,R4/2
L13	Radial flow compressors and pumps - general analysis, expression for degree of reaction	Chalk & Board	1,2,12	3,4,5	T1/2,R1/3, R3/2,R4/2
L14	Velocity triangles, effect of blade discharge angle on energy transfer and degree of reaction.	Chalk & Board		3,4,5	T1/2,R1/3, R3/2,R4/2
L15	Effect of blade discharge angle on performance, Theoretical head – capacity relationship	Chalk & Board		3,4,5	T1/2,R1/3, R3/2,R4/2
L16	General analysis of Axial flow pumps and compressors degree of reaction, velocity triangles, Numerical	Chalk & Board		3,4,5	T1/2,R1/3, R3/2,R4/2
L17	Numerical	Chalk & Board		3,4,5	T1/2,R1/3, R3/2,R4/2
T7	Numerical	Chalk & Board		3,4,5	T1/2,R1/3, R3/2,R4/2
T8	Numerical	Chalk & Board		3,4,5	T1/2,R1/3, R3/2,R4/2
T9	Numerical	Chalk & Board		3,4,5	T1/2,R1/3, R3/2,R4/2

Exercise	COs attained
1. Derive an expression for Euler's Turbine equation.	3,4,5
2. Draw the velocity triangle diagrams at the tips of a rotor and derive alternate form of Euler's Turbine equation. Also write these two equations for power absorbing turbo machine.	
3. Describe the significance of components of energy transfer.	
4. Explain Impulse and reaction type turbomachine. Define degree of reaction.	
5. Explain in brief general analysis of an impulse and reaction turbomachine. Write the effect of blade discharge angle on energy transfer. Writer the values of degree of reaction for impulse and reaction type turbomachine.	
6. Analyze a radial flow turbomachine. Draw the velocity triangle diagram at inlet and for different discharge angles at outlet. Derive an expression for energy transfer in terms of blade discharge angles. Also derive an equation for Degree of Reaction in terms of blade discharge angles.	

7. Draw on a common graph. (1) Energy transfer versus blade discharge angles and Degree of reaction versus blade discharge angles. Then write the effect of blade discharge angle on (i) Energy transfer and (ii) Degree of reaction.	
8. Describe in brief theoretical head-capacity relationship.	
9. A turbine has the following data. Water is directed at an angle of 300 to the tangent. Degree of reaction is 0.45, utilization factor is 0.895. The absolute velocity at exit is axial, water enters the rotor with a static pressure 500 kPa and stagnation pressure of 750 kPa. Calculate (a) the inlet blade angle and (b) the work output for a mass flow rate of 10 kg/s.	
10.The following data refers to an axial flow device. Flow velocity from exit of the nozzle:Vm1 = 190 m/s Degree of reaction: R = 50% Blade speed: U1 = U2 =U = 180 m/s, Entry stagnation temperature: T01 = 380 K, Entry static temperature:T1 = 300 K. Calculate (a) the maximum utilization factor, (b) the rotor blade angle at inlet and exit and (c) the power, it the mass flow rate is 10kg/s.	
11. The discharge blade angles are 200 each for both the stator and rotor. The steam exit from the fixed blade is 150 m/s. The mass flow rate of the steam is 3.5 kg/s. The ratio of Vm/u at the exit is 0.75. Calculate. (a) Inlet rotor blade angle (b) The power developed (c) The degree of reaction (d) Utilization factor for optimum speed ratio	
12. An axial flow turbine stage has a flow coefficient of 0.7, a constant axial velocity and the gas leaves the stator blades at an angle of 650 to the axial direction. Calculate (a) the rotor inlet and exit angles and (b) the degree of reaction.	
13. Analyze axial flow compressor and pump. Derive modified energy equation relating blade speed, axial velocity and fluid angles at blade inlet and outlet w.r.t. axial direction. Draw the combined velocity triangles diagram on (i) common base of blade speed and (ii) common apex.	3,4,5
15. Draw the combined velocity triangle diagram for the value of (i) R = 0.5 (ii) 1>R>0.5 and R>1.	
16. Define Utilization factor. Write its equation. Define vane efficiency. What is the product of utilization factor and vane efficiency?	
17. Derive the relation between Utilization factor and degree of reaction for axial flow turbo machine.	
18. Draw the velocity triangles diagram for R < 0, R = 0, R = ½, R = 1,R > 1.	
19. What should be the condition for maximum Utilization factor? Prove that $\varepsilon = \frac{\cos^2\alpha}{1-R\sin^2\alpha}$ and analyse it.	
20. Define blade speed ratio. Derive an expression for the optimum speed ratio of an impulse Turbine. Explain with graph how ε_{max} is related with blade speed ratio for R = 0 and $\alpha = 20^0$.	
21. Prove that for reaction turbine for special case of R = 1. $\varepsilon = \frac{1}{1+\frac{V_1}{4u\cos\alpha}}$ Also prove that for 50 % reaction turbine. $\varepsilon = \frac{\cos^2\alpha}{1-1/2\sin^2\alpha}$	
22. Prove that for Parsons steam turbine $\varepsilon_{max} = 2\cos^2\alpha/(1+\cos^2\alpha)$.	

23. An inward flow turbine has 0.6 reaction. The blade speed at entry is 12 m/s and the radial velocity of flow is constant at 2.4 m/s. The rotor diameter at entry is twice that at exit. Find the utilization factor angles of the blades at entry and exit assuming there is no exit whirl velocity and no friction loss. Is the utilization factor maximum?	
24. The following data refers to a turbomachine. Inlet velocity of whirl = 16 m/s, velocity of flow = 10 m/s, blade speed = 33 m/s, outlet blade speed = 8 m/s. Discharge is radial with an absolute velocity of 16 m/s. If water is the working fluid flowing at the rate of 1 m3/s. Calculate the following: Power in kW, Change in total pressure in kN/m2 , Degree of reaction, Utilization factor	

MODULE-3: STEAM & REACTION TURBINES	**Planned hours: 10**

Learning objectives: At the end of this module student should be able to:

- Explain the construction, working, types and classification of a steam turbine.
- Explain the condition for maximum blade efficiency, stage efficiency.
- Explain compounding - Need for compounding, Method of compounding.
- Explain impulse staging – Condition for maximum utilization factor for multi stage turbine with equiangular blades.
- Analyze the effect of blade and nozzle losses.
- Explain Reaction turbine and Parson's reaction turbine, Discuss Condition for maximum blade efficiency, reaction staging..

Lecture No.	Topics covered	Teaching Method	POs attained	COs attained	Reference Book/Chapter No.
L18	Classification, Single stage impulse turbine,	Chalk & Board and Video animation	1,2,3,6,12	3	T1/4,R3/6,R4/6
L19	Condition for maximum blade efficiency, stage efficiency,	Chalk & Board		3	T1/4,R3/6,R4/6
L20	Compounding - Need for compounding, Method of compounding,	Chalk & Board		3	T1/4,R3/6,R4/6
L21	Impulse staging – Condition for maximum utilization factor for multi stage turbine with equiangular blades; effect of blades and nozzle losses.	Chalk & Board		3	T1/4,R3/6,R4/6
L22	Reaction turbine; Parson's reaction turbine,	Chalk & Board		3	T1/4,R3/6,R4/6
L23	Condition for maximum blade efficiency, reaction staging.	Chalk & Board		3	T1/4,R3/6,R4/6
L24	Numerical	Chalk & Board	1,2,3,6,12	3	T1/4,R3/6,R4/6
L25	Numerical	Chalk & Board		3	T1/4,R3/6,R4/6
T10	Numerical	Chalk & Board		3	T1/4,R3/6,R4/6
T11	Numerical	Chalk & Board		3	T1/4,R3/6,R4/6

T12	Numerical	Chalk & Board		3	T1/4,R3/6,R4/6
T13	Numerical	Chalk & Board		3	T1/4,R3/6,R4/6
T14	Numerical	Chalk & Board		3	T1/4,R3/6,R4/6

Exercise	**COs attained**
1. Define steam turbine, and classify it.	
2. With the help of neat arrangement along with the variation of pressure and velocity explain the working of simple impulse steam turbine.	
3. What is compounding? Explain with sketches (i) Velocity compounding (ii) Pressure compounding and (iii) Pressure – Velocity compounding.	
4. Explain with sketch working of Reaction steam Turbine.	
5. Compare impulse and Reaction steam turbine.	
6. Write the advantage of steam turbine over other prime movers.	
7. Draw the velocity triangles at the inlet and outlet tips of blades of single stage impulse turbine; combined the velocity diagrams and derive an expression for i) Work done, ii) Power developed, iii) Blade or diagram efficiency etc.	
8. Describe the effect of friction on blade efficiency.	
9. What is speed ratio? Derive the condition of speed ratio for maximum blade efficiency.	
10. Write an expression for i) Gross stage efficiency and ii) Axial thrust.	
11. Describe with combined velocity diagrams two stage impulse turbine. Write an expression for i) blade efficiency ii) maximum blade efficiency and iii) maximum work done per kg of steam.	
12. Explain in brief i) blade parameter ii) Reheat Factor iii) Reaction staging.	3
13. The mean diameter of the blades of an impulse turbine is 85cm and the speed is 3200 rpm. The nozzle angle is 20^0 and the ratio of blade speed to steam speed is 0.45. The blade velocity coefficient is 0.85. The outlet angle of blade is 2^0 less than the blade angle at the inlet. The steam flow is 9 kg/s. Draw the velocity triangles and determine the following: a) Tangential and axial thrust on the blades b) Resultant thrust on the blades c) Power developed and blade efficiency	
14. The following particulars refer to a single impulse turbine. Mean diameter of blade ring=2.5 m, speed=3000 rpm, nozzle angle=20^0, ratio of blade velocity to steam =0.4, blade friction factor=0.8, blade angle at exit is 3^0 less than that at the inlet. Steam flow developed and (b) the blade efficiency.	
15. A De Laval turbine has a mean rotor diameter of 0.55 m and runs at 3300 rpm. The speed ratio is 0.45 and the nozzle angle at the rotor inlet is 200. The blade velocity coefficient is 0.91. Assuming equiangular blades, find the rotor blade angles at the inlet and outlet. If m=10 kg/s. Find the power output and the axial thrust.	
16. The following particulars refer to a stage of a Parsons steam turbine. The mean diameter of the blade ring is 70cm, the steam velocity at the inlet of moving blades is 160 m/s, the outlet blade angle of moving blade β_2 is 20^0. The steam flow through the blades is 7 kg/s, speed 1500 rpm and η is 0.8. Draw the velocity diagram and find the following:	

a) Blade inlet angle b) Power developed in the stage c) Available isentropic enthalpy drop.	
17. In a Parson's turbine running at 1500 rpm, the available enthalpy drop for an expansion is 63kJ/kg. If the mean diameter of the rotor is 100 cm, find the number of moving rows required. Assume that efficiency of a stage is 0.8, blade outlet angle 20^0 and speed ratio 0.7.	

MODULE-4: HYDRAULIC & FRANCIS TURBINES	Planned hours: 10

Learning objectives: At the end of this module student should be able to:

- Explain the construction, working and classification of water turbine.
- Explain the working principle of Pelton wheel & how to draw velocity triangles.
- Explain design parameters of Pelton wheel.
- Explain Francis turbine, its velocity triangles, runner shapes for different blade speed and its design.
- Explain draft tubes and its types.
- Explain Kaplan and propeller turbines, its design parameters and velocity triangles.

Lecture No.	Topics covered	Teaching Method	POs attained	COs attained	Reference Book/Chapter No.
L26	Classification, Different efficiencies, Pelton turbine – velocity triangles, Condition for Maximum efficiency of Pelton wheel.	Chalk & Board, Lab Visit.	1,2,3, 6,12	4,5	T1/6,R3/7,R4/7
L27	Condition for Maximum efficiency of Pelton wheel.	Chalk & Board		4,5	T1/6,R3/7,R4/7
L28	Design parameters; Function of a Draft tube, types of draft tubes	Chalk & Board		4,5	T1/6,R3/7,R4/7
L29	Francis turbine – velocity triangles, runner shapes for different blade speeds.	Chalk & Board, Lab Visit.		4,5	T1/6,R3/7,R4/7
L30	Design of Francis turbine; Kaplan and Propeller turbines - velocity triangles and design parameters.	Chalk & Board		4,5	T1/6,R3/7,R4/7
T15	Numerical.	Chalk & Board		4,5	T1/6,R3/7,R4/7
T16	Numerical.	Chalk & Board, Lab Visit.		4,5	T1/6,R3/7,R4/7
T17	Numerical.	Chalk & Board		4,5	T1/6,R3/7,R4/7
T18	Numerical.	Chalk & Board		4,5	T1/6,R3/7,R4/7
T19	Numerical.	Chalk & Board		4,5	T1/6,R3/7,R4/7

Exercises	COs attained

1. What is hydraulic Turbine? Classify it. Sketch the layout of hydro electric power plant.	4,5
2. Define i) hydraulic efficiency, ii) mechanical efficiency iii) overall efficiency and volumetric efficiency.	
3. What are the main components of Pelton Turbine? Explain their function.	
4. Draw the velocity triangles diagrams at bucket inlet and outlet and write an expression for Force, work, power and efficiency; maximum hydraulic efficiency with its condition.	
5. Sketch Francis Turbine, Label its main components and explain its working.	
6. Draw the velocity triangle diagrams at radial inward flow Francis turbine and derive an expression for (i) Work done, (ii) Hydraulic efficiency.	
7. Sketch Kaplan Turbine, Label its main components and explain its working.	
8. What is a draft tube? What are its functions? What are its types? Derive an expression for -ve head created at the runner outlet by using a draft tube.	
9. A Pelton wheel develops 5800 kW under a net head of 180 m at a speed of 195rpm. Find the discharge through the turbine, the wheel diameter, the number of jets required and the specific speed. Use the following assumptions: overall efficiency 86%, D/d =12, ϕ=0.45 and C_V=0.985.	
10. A Pelton wheel has a water supply rate of 5 m^3/s at a head of 256 m and runs at 500 rpm. Assuming a turbine efficiency of 0.85, a co efficient of velocity for nozzle as 0.985, speed ratio of 0.46. Calculate (a) the power output (b) the number of jets, (d) the diameter of the wheel (e) the jet diameter (f) the number of Pelton cups and (g) the cup dimensions.	
11. The following data pertains to Francis turbine. Shaft power=1000 kW, head=200 m, overall efficiency=85%, speed=540 rpm, velocity of flow at inlet=9 m/s. The ratio of width to diameter of wheel at inlet=1/10, hydraulic efficiency = 87%, area occupied by thickness of blades=7.5%. Find (a) the area of flow, (b) the angle of entry (c) the tangential velocity and (d) the velocity of whirl at the inlet if the discharge is radial.	
12. A Kaplan turbine runner is to be designed to develop 9000 kW. The net available head is 6m. If the speed ratio is 2.01 and the flow ratio 0.7, overall efficiency 87%, the diameter of boss being 1/3 rd of the diameter of runner. Find the diameter of the runner, its speed and the specific speed of the turbine.	

Module-5: CENTRIFUGAL PUMPS , AND COMPRESSORS	Planned hours: 10

Learning objectives: At the end of this chapter student should be able to:

- Explain the construction, working and classification of Centrifugal pump.
- Explain suction, delivery and manometric heads, pressure rise in the impeller, and various efficiency terms like manometric efficiency, hydraulic efficiency, volumetric efficiency and overall efficiency.
- Explain multistage centrifugal pumps, minimum starting speed, slip, priming, cavitation N.P.S.H.
- Explain the construction and working of Centrifugal and an axial flow compressors.
- Analyze blade angles at impeller eye root and eye tip; slip factor and power input factor, width of the impeller channel.
- Analyze diffuser design: Flow in the vane less space, determination of diffuser inlet vane angle, width and length of the diffuser passages; Surging of centrifugal compressor

Lecture No.	Topics covered	Teaching Method	POs attained	COs attained	Reference Book/Chapter No.
L31	Classification and Parts of Centrifugal pump.	Chalk & Board		5	T1/7,R3/8,R4/4

L32	Definition of terms used in the design of centrifugal pump like Suction head, delivery head, manometric head, pressure rise in impeller. Manometric efficiency, hydraulic efficiency, volumetric efficiency, overall efficiency.	Chalk & Board, Lab Visit	1,2,3,6,12,	5	T1/7,R3/8,R4/4
L33	Multistage centrifugal pumps, minimum starting speed.	Chalk & Board		5	T1/7,R3/8,R4/4
L34	Priming, cavitation, NPSH. Pumps in series and parallel	Chalk & Board		5	T1/7,R3/8,R4/4
T20	Numerical	Chalk & Board		5	T1/7,R3/8,R4/4
T21	Numerical	Chalk & Board		5	T1/7,R3/8,R4/4
L35	Centrifugal Compressor; Stage Velocity triangles, Efficiencies and stalling. Numerical	Chalk & Board	1,2,3,6,12	5	T1/5,R3/4,R4/4
L36	slip factor and power input factor, stage work, pressure developed, stage efficiency	Chalk & Board		5	T1/5,R3/4,R4/4
L37	surging and problems, Axial Flow Compressors: Classification; Expression for pressure ratio developed per stage – work done factor,	Chalk & Board		5	T1/5,R3/4,R4/4
T22	Numerical	Chalk & Board ,Lab Visit		5	T1/5,R3/5,R4/5
T23	Numerical	Chalk & Board		5	T1/5,R3/5,R4/5
T24	Numerical	Chalk & Board		5	T1/5,R3/5,R4/5

Exercise	**COs attained**
1. What is centrifugal pump? With a neat sketch explain briefly the Parts & working principle of a Centrifugal pump.	5
2. How a centrifugal pump is classified. Explain each one with neat diagram.	
3. Explain the following heads of a centrifugal pump: (i) Suction head, (ii) Delivery head, (iii) Static head, (iv) Manometric head & (v) Total or gross or effective head.	
4. Derive an expression for work done by impeller of a centrifugal pump	
5. Define and write an expression for the following efficiencies of centrifugal pump:(i) Mechanical efficiency, (ii) Manometric efficiency, (iii) overall efficiency and (iv) Hydraulic efficiency	
6. Derive an expression for pressure rise in pump impeller.	
7. Derive an expression for minimum starting speed of a centrifugal pump.	
8. What do you mean by ideal, virtual and Manometric Heads of a centrifugal pump What is slip?	
9. What is cavitation? What are the bad effects of cavitation? Write an expression for Thoma cavitation factor and explain each term.	
10. Write in brief (i) Net positive suction head. (ii) Characteristics of centrifugal pump. (iii) Priming. (iv) Surging and choking.	

11. A centrifugal pump delivers 1800 lit/min against a total height of 20m. Its speed is 1450rpm. Inner and outer diameters of impeller are 120mm and 240mm respectively and the diameter of suction and delivery pipes are both 100mm. Determine the blade angles β_1 and β_2 of the impeller vane if the water enters radially. Neglect friction and other losses.	
12. A centrifugal pump having outer diameter equal to two times the inner diameter and running at 1000 rpm works against a total head of 4m. The velocity of flow through the impeller is constant and equal to 2.5 m/s. The vanes are set back at an angle of 400 at outlet. If the outer diameter of the impeller is 50cm and width at outlet is 5 cm. determine (a) the vane angle at the inlet, (b) the work done per second by the impeller on water, and (c) the Manometric efficiency.	
13. A centrifugal pump runs at 950 rpm. Its outer and inner diameters are 500 mm and 250 mm. The vanes are set back at 350 to the wheel rim. If the radial velocity of water through the impeller is constant at 4 m/s. Find (a) the angle of vane at the inlet (b) the velocity if water at the outlet (c) the direction of water at the outlet and (a) the work done by the impeller per kg of water. Entry of water at inlet is radial.	
14. What is centrifugal compressor? With a neat sketch explain its main parts. Further explain with sketches impeller and diffuser.	5
15. Describe the principle of operation of centrifugal compressor.	
16. Derive an expression for work done by impeller.	
17. Explain in brief i) Power input factor. ii) Effect of slip and power input factor on pressure ratio. iii) Slip factor.	
18. Explain in brief the design part of impeller and diffuser blades like it's a width, angles shapes etc.	
19. Explain with sketches velocity triangle diagrams for different impeller shapes.	
20. Why pre whirl is required? Explain it with sketches w.r.t. the eye of impeller.	
21. Air at a temperature of 290 K, flows in a centrifugal compressor running at 20,000 rpm, slip factor=0.8, η_{t-1}=0.80, d2=0.60m. Assume that the absolute velocities at the inlet and outlet are same. Calculate (a) the temperature rise of air passing through the compressor and (b) the stage pressure ratio.	
22. Free air delivered by a compressor is 20 kg/min. The inlet conditions are 1 bar and 200c static. The velocity of air at the inlet is 60 m/s. The isentropic efficiency of the compressor is 0.7. The total head pressure ratio is 3. Find (a) the total head temperature at the exit and (b) the power required by the compressor if the mechanical efficiency is 95%.	
23. A two stage centrifugal compressor delivers 500 m3 of free air per min. The suction conditions are 1 bar and 150c. The compression ratio and isentropic efficiency of each stage are 1.25 and 80% respectively. Find the isentropic efficiency for the entire compression process.	
24. With the help of neat sketch explain the construction and working principle of axial flow compressors	
25. Sketch and explain the axial compressor stage velocity triangles and derive an expression for (i) ratio of blade speed to velocity of flow (ii) degree of reaction. Also writer conditions for 50% R.	
26. Derive an expression for work input to compressor. Also describe work done factor.	
27. Describe in brief (i) Compressor stage efficiency (ii) Degree of Reaction (iii) Radial pressure gradient.	
28. Explain Radial equilibrium condition for axial flow machines for (i) free vortex flow (ii) Forced vortex flow and (iii) constant reaction flow.	
29. Design blades using (i) single air foil theory and (ii) cascade theory.	

30. Air enters a three stage axial compressor at 1 bar and 300K. The energy input is 25 kJ/kg per each stage. The stage efficiency is 0.86. Calculate (a) the exit static temperature (b) the compressor efficiency and (c) the static pressure ratio.	
31. The ambient conditions at inlet are 200c and 1 bar. At exit the total head temperature and pressure are 150^0c and 3.5 bar, and static pressure at exit is 3 bar. Calculate (a) the isentropic efficiency (b) the Polytropic efficiency and (c) the air velocity at exit.	
32. An axial compressor stage has the following data. Stagnation temperature and pressure at entry are 200c and 1 bar, and the degree of reaction is 50%. Flow co-efficient ϕ = 0.5 Mean blade ring diameter dm=35cm, Speed N = 18,000 rpm Air angles at rotor and stator exit $\alpha 1 = \beta 1 = 60^0$,Blade height at entry h = 5 cm Work done factor ϕ= 0.88,Isentropic efficiency ηct-t = 0.85 Mechanical efficiency ηm =0.96 Calculate (a) the air angles at the rotor and stator entry (b) the mass flow rate of air (c) the power required to drive the compressor (d) the loading co-efficient (e) the pressure ratio developed by the stage and (f) Mach number at the rotor entry.	

Assignment -I

SL No	Questions	COs
1.a	Define Turbo machine with a neat sketch explain the main parts of turbomachine and give classification of turbo machines also compare Turbomachines with Positive displacement machines	1
b	Give the significance of the following non dimensional parameters i) Discharge co-efficient ii) Head or pressure or energy co-efficient (iii) Power co-efficient (iv) Reynolds number v) specific speed and write its expressions for pump and turbines	1,2
2 a	A single stage centrifugal pump works against a height of 30m, running at 200 rpm, supplies 3 m^3/s and has an impeller diameter of 300 mm. Calculate the number of stages. b) The diameter of each impeller required to pump 6 m^3/s of water to a height of 220m when running at 1500 rpm.	1,2
2 b	Test on a Turbine runner 1.25 m in diameter at 30 m head gave the following results power developed = 736 kW speed is 180 rpm & discharge is 2.7 m^3. Find the diameter, speed & discharge of a runner to operate at 45 m head and give 1472 Kw at the same efficiency. What is the specific speed of the Turbines?	1,2
2c	Derive an expression for (i) total to total efficiency (ii) total to stagnation efficiency (iii) Stagnation to total efficiency and (iv) Stagnation to stagnation efficiency of expansion process.	
3 a	Derive Alternate or Modified form of an Euler Turbine Equation & explain the significance of each component in brief.	3, 4 5
3 b	Write the Equation/ Relation for the Energy transfer & Degree of Relation for a Generalized Turbo machine. Discuss the effect of the blade discharge angle on Energy transfer & Degree of reaction with necessary diagrams	3,4 5
4 a	Define degree of reaction and utilization factor with mathematical expressions show that $\varepsilon = (V1^2 - V2^2) / (V1^2 - RV2^2)$.	3,4 5
4 b	Show that ε max of an axial flow turbine with degree of reaction =1/3 the relationship of blade speed U to absolute velocity at rotor inlet V1, should be U/ V1 = (3/4) cosα1 .	3,4 5
5 a	A mixed flow turbine handling water operates under a static head of 65 m. In a steady flow the static pressure at the rotor inlet is 3.5 atm. (gauge). The absolute velocity at the rotor has no axial component and is directed at an angle of 25^0 to the tangent of wheel so that Vu1 is positive. The absolute velocity at exit purely axial. If the degree of reaction for the machine is 0.47 and utilization factor is 0.896, compute the tangential blade speed at inlet as well as the inlet blade angle β1. Find also the work output per	3,4 5

	unit mass of water.	
5 b	An inward flow reaction turbine has outer diameter and inner diameter of the wheel as 1 m and 0.5 m respectively the vanes are radial at inlet and the discharge is radial at outlet and water enters the vanes at an angle of 10^0. Assuming the velocity of flow to be constant and equal to 3 m/s. Find i) Speed of the wheel. ii) the vane angle at outlet iii) Degree of Reaction R.	3,4 5

Assignment –II

SL No	Questions	COs
1 a	Prove that the Maximum efficiency with equiangular rotor blades for Curtis stage is given by $\eta_{max} = \cos^2\alpha 1$. Dry Saturated steam at 10 bar is supplied to single rotor impulse wheel, the condenser pressure being 0.5 bar with the nozzle losses of 16% and the nozzle angle at the rotor inlet is 72^0 to the axis of rotation. The rotor blades which move with a speed of 450 m/s are equiangular. If C_b =0.92, find i) Specific power output ii) Rotor efficiency iii) Stage efficiency iv) Direction of exit steam	3,4,5
b	Derive an expression for maximum efficiency of a Parson's Turbine. In a Curtis stage with two rows of moving blades, the rotors are equiangular. The first rotor has angle of 29^0 each while second rotor has angle of 32^0 each. The velocity of steam at the exit of nozzle is 530 m/s and the blade coefficients are 0.9 in the first, 0.95 in the stator and in the second rotor. If the absolute velocity at the stage exit should be axial, find i) Mean blade speed ii) The rotor efficiency iii) The power output for a flow rate of 115.2 tons/hr.	3,4,5
2 a	A Pelton wheel is working under a gross head of 400m. The water is supplied through penstock of diameter 1m and length of 4 Km from reservoir to the Pelton wheel. The coefficient of friction for the penstock is given as 0.008. The jet of water of diameter 150 mm strikes the buckets of the wheel and gets deflected through an angle of 165^0. The relative velocity of water at outlet is reduced by 15% due to friction between inside surface of the bucket and water. If the velocity of the buckets is 0.45 times the jet velocity at inlet and mechanical efficiency is 85%, determine i) Power given to the runner, ii) shaft power, iii) hydraulic and overall efficiency. For Francis turbine, Show that the hydraulic efficiency = $\frac{2}{2+\tan^2\alpha 1}$ where $\alpha 1$ = flow angle at inlet, and given that 1) component of velocity normal to the tangential direction is constant from inlet to outlet 2) Relative velocity at the inlet is radial 3) absolute velocity at outlet is radial. Sketch the velocity triangles.	3,4,5
2 b	What is Draft tube? List the different types and functions of draft tube. Explain the construction features and working of Kaplan turbine	1,2
3 a	An inward flow reaction turbine with radial discharge with an overall efficiency of 80 % is required to develop 147 kW. The head is 8 m. peripheral velocity of the wheel is $0.96\sqrt{2gH}$ the radial velocity of flow is $0.36\sqrt{2gH}$. The wheel is to make 150 rpm and the hydraulic losses in the turbine are 22 % of the available energy. Determine i) the angle of guide blade at inlet. ii) Wheel vane angle at inlet iii) diameter of wheel.	3,4,5
3 b	Define the following i) Priming and its need ii) Manometric head iii) Cavitation iv) NPSH Derive the expression for minimum starting speed of the pump.	3,4,5
4 a	The following details refer to a centrifugal pump. Outer diameter = 30cm. Eye diameter = 15 cm. Blade angle at inlet = 30°. Blade angle at outlet = 25°. Speed 1450 rpm. The flow velocity remains constant. The whirl at inlet is zero. Determine the work done per kg. If	

	the manometric efficiency is 82%, determine the working head. If width at outlet is 2 cm, determine the power, overall efficiency η_0 = 76%.	3,4,5
5 a	A centrifugal pump has an impeller diameter of 25 cm and width of 7.5 cm at exit. It delivers 120 lit/s of water against a head of 24 m at 1440 rpm. Assuming the vane blocks the area of flow by 5 % and a hydraulic efficiency of 0.85, estimate the vane angle at exit. Also calculate the torque exerted on the driving shaft if the mechanical efficiency is 95 %. A 3 stage pump has impeller 40 cm in diameter and 2 cm width at outlet. The vanes are curved back at angle of 450 with tangential direction and reduced the circumferential by 10 %. The manometric efficiency is 90 % and the overall efficiency is 80 %. Find the head generated by the pump when running at 1000 rpm and delivering 50 lit/s. what should be the shaft power?	3,4,5
5 b	Explain in brief i) Power input factor. ii) Effect of slip and power input factor on pressure ratio. iii) Slip factor. Free air delivered by a compressor is 20 kg/min. The inlet conditions are 1 bar and 200c static. The velocity of air at the inlet is 60 m/s. The isentropic efficiency of the compressor is 0.7. The total head pressure ratio is 3. Find (a) the total head temperature at the exit and (b) the power required by the compressor if the mechanical efficiency is 95%.	5

Syllabus for the Continous Internal Evaluation (CIE) Tests (Tentative):

Internal Assessment Test-I	Module 1-Full, Module 2-Half
Internal Assessment Test-II	Module 2-Remaining, Module 3-Full
Internal Assessment Test-III	Module 4-Full, Module 5-Full
Test pattern: Four questions will be given and students have to answer any two full questions. Each question carries 15 marks.	

Question paper pattern:

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

Contents beyond syllabus to meet POs:	**Topics covered**	**POs attained**
	Modelling/Mini project/Think Pair Share (TPS) activities	1,2,6,7,9,10,12

ACTIVITY TO BE CONDUCTED:

An activity has to be conducted for students of fifth semester in related to the course Turbomachines for the topic titled as “How to Draw Velocity Triangles” for steam and Hydraulic turbines which covers CO3.

Teaching Methodology:-

1. Chalk and Talk
2. Power Point Presentations/Animations/NPTEL Videos, ICT enabled activities, etc.
3. Regular review of students through question & answer interaction based on topics covered in the class room, Assignment, etc.

List of Open Source/learning website:

1. http://164.100.133.129:81/econtent/Uploads/01-PT11Intro2Turbomachines%20%5BCompatibility%20 Mode%5D.pdf
2. https://www.youtube.com/watch?v=TiJZp-KB6h8
3. https://www.youtube.com/watch?v=UYMDm4yB1QA

4. https://www.youtube.com/watch?v=xJpl-BQV52M
5. https://www.youtube.com/watch?v=DylZzVflmlM
6. https://www.youtube.com/watch?v=MQWHr3Of4VM
7. https://www.youtube.com/watch?v=8deGbeRrTk4

Website related to the course – TURBOMACHINES

1. **https://sites.google.com/a/gmit.ac.in/tmdgr/**

Assessment Methods:-

Three Internal Test, 30 Marks each average of three tests will be taken and add 10 marks for assignment/activity conducted to make total of 40 marks for evaluation. Course Project/Model making, etc (if needed). Final examination, of 60 Marks will be conducted by the university and the result will be **analyzed as per 2018 scheme norms.**

TURBOMACHINERY LABORATORY

Performance testing of Turbo machines;

1. Pelton wheel
2. Multi stage centrifugal pumps
3. Performance test on an Air Blower
4. Reciprocating pump
5. Performance test of a two stage Reciprocating Air Compressor

Course Outcome to Program Outcome (POs) & Program Specific Outcome (PSOs) Mapping :-

Course Outcomes (COs)	Program Outcomes (POs)												Program Specific Outcomes (PSOs)	
	PO1	PO2	PO3	PO4	PO5	PO6	PO7	PO8	PO9	PO10	PO11	PO12	PSO1	PSO2
CO1	1	1	1	---	---	1	---	1	---	---	---	1	1	2
CO2	1	2	1	---	---	2	---	1	---	---	---	1	1	---
CO3	2	2	1	---	1	2	---	1	1	---	---	1	2	---
CO4	1	2	1	1	---	2	1	1	2	1	1	1	1	1
CO5	1	2	2	---	---	1	1	---	1	1	---	1	1	2

Enter correlation levels 1, 2, or 3 as defined below:

1. Slight (Low) 2. Moderate (Medium) 3. Substantial (High)

If there is no correlation, put " - "

JUSTIFICATION FOR MAPPING OF POs & PSOs:

1. Since this course briefs about the concept of rotary/swirling machines which is fundamental thing for any learner to understand.
2. Some of the things in this course have a moderate impact on various parameters like, components of steam and hydraulic turbines, effect of fixed/guide blade angle, etc.
3. Parameters like, mass flow rate, degree of reaction, utilization factor, work done, power generation, etc have a greater impact on power generation/power absorbing type of turbomachines

(Dr. Rajakumar D.G and Mr. Mallikarjuna V. Bidari.)
Course Coordinators