**Department of Mechanical
Engineering,AmritaSchool of Engineering
AmritapuriCampus,Kollam,Kerala,India.**

Master of Technology (M.Tech.)
in
Thermal and Fluids Engineering

Curriculum and Syllabus

Revised on: May2025

Previous revisions:2023, 2021,2017,2015,2011

Preface

As the energy and process sector in India is in a boom, the need of the hour is engineers with strong background in thermal and fluid sciences capable of carrying out conceptual design. The program is aimed at providing sufficient theoretical, computational and experimental knowledge in the thermal and fluid sciences. It also encapsulates simulation and experimental skills applied to IC engines, power plant, aerospace and gas turbines research. The program is designed to equip students to perform design related to linear and nonlinear steady state/ transient heat transfer, steady and unsteady fluid flow, multiphase flows, fluid structure interactions viz., estimation of thermal and pressure loads and coupled field analysis.

The program provides required numerical simulation techniques for design and analysis of equipment like gas turbines and accessories, steam turbines and reactor pipes, heat exchangers, compressors, turbines, pumps, propellers, rotor stator interactions, flow separators, inlet manifolds, volutes, turbo chargers etc. The program includes adequate courses for numerical analysis and computer simulation of thermal engineering problems. The course also introduces the student to experimental techniques like flow visualization, combustion diagnostics, particle characterization and other recent imaging techniques adopted in the field of thermal research. As automation is being introduced in various fields of research and industry, new courses covering these topics are also included. Stu-dents will be eligible for the post of design/research engineers in industries related thermal and fluid sciences. This program provides excellent background needed to employment in various R & D organizations and also for high quality academic research.

Program Educational Objectives of the M.Tech (Thermal & Fluids Engineering)

PEO1: This program offers a state-of-the-art academic curriculum designed for students from Mechanical Engineering, Aerospace Engineering, and Chemical Engineering, exposing them to various subjects related to thermal and fluid engineering and providing the necessary technical knowledge to master the field.

PEO2: This program offers a comprehensive educational environment, enabling students to gain expertise in various thermo-fluid systems of practical relevance.

PEO3: Expose students to the designed coursework and practical thermo-fluid systems, and prepare them to become engineers/designers in industries, researchers in academia and R&D organizations.

Program Outcomes (POs)

PO1: An ability to independently carry out research /investigation and development work to solve practical problems.

PO2:Anability to write and present a substantial technical report/document.

PO3: Students should be able to demonstrate a degree of mastery over the area as per the specialization of the program. The mastery should be at a level higher than the requirements in the appropriate bachelor's program.

Program Specific Outcomes (PSOs)

PSO1: Apply the concepts to solve problems related to thermal and fluids engineering using modern tools.

PSO2: Empower the students to provide cost-effective solutions for industry and societal problems.

CURRICULUM
M.TECH. THERMAL AND FLUIDS ENGINEERING(TFE)

First Semester

Course Code	Type	Course	LT P	Credits
25MA605	FC	Advanced Engineering Mathematics	30 3	4
25TF601	FC	Advanced Fluid Dynamics	210	3
25TF602	FC	Advanced Heat Transfer	2 10	3
25TF603	FC	Advanced Engineering Thermodynamics	2 10	3
25TF604	SC	Machine learning	303	4
25TF681	FC	Experimental Methods	003	1
25RM609	SC	Research Methodology	200	2
25AVP501	HU	Mastery over Mind	1 0 2	2
22ADM501	HU	Amrita Value Program*	2 0 1	P/F
23HU601	HU	Career Competency-I*	0 0 3	P/F
			Credits	**22**

*Non-credit course

Second Semester

Course Code	Type	Course	LT P	Credits
25TF611	SC	Computational Fluid Dynamics and Heat Transfer	303	4
25TF612	SC	Introduction to Deep Learning	303	4
25TF613	SC	Automation and IoT	3 00	3
25TF699		Project Seminar	003	1
25TF682	SC	Advanced Thermal & Fluids Eng. Lab	103	2
	E	Elective I	300	3
	E	Elective II	300	3
23HU611	HU	Career Competency-II	0 0 3	1
25TF698		Industry Internship	0 0 2	1
			Credits	**22**

Third Semester

Course Code	Type	Course	LT P	Credits
25TF798	P	Dissertation–Stage I	0 0 22	11
			Credits	**11**

FC – Foundation Core, SC – Subject Core, E – Elective, HU – Humanities, P - Project

Fourth Semester

Course Code	Type	Course	LT P	Credits
25TF799	P	Dissertation–Stage II	0 0 30	15
			Credits	**15**

Total Credits for M.Tech. Program:70

Electives (Elective I & II)

Code	Course	LT P	Credits
Fluid Stream			
25TF631	Aerodynamics	300	3
25TF632	Bio-fluid mechanics	300	3
25TF633	Boundary Layer Theory	300	3
25TF634	Fluid Structure Interaction	300	3
25TF635	Introduction to Turbulence	300	3
Thermal Stream			
25TF641	Computational methods for Micro and Nano Scale Thermal Systems	300	3
25TF642	Cryogenics	300	3
25TF643	Heat Exchange Equipment	300	3
25TF644	HVAC and Refrigeration	300	3
25TF645	IC Engine Systems, Combustion and Emissions	300	3
25TF646	Inverse Heat Transfer	300	3
25TF647	Micro and Nano Scale Thermal Engineering	300	3
25TF648	Two-phase Flow and Heat Transfer	300	3
Automation/Energy Systems			
25TF651	Fuel Cell Technology and Hydrogen Energy	300	3
25TF652	Instrumentation and Process Control	300	3
25TF653	Introduction to data-driven methods	300	3
25TF654	Machine Learning and Artificial Intelligence	300	3
25TF655	Nuclear Reactor Thermal-Hydraulics and Safety	300	3
25TF656	Power Plant and Thermal Systems Engineering	300	3
25TF657	Renewable Energy	300	3
25TF658	Turbo machines	300	3

SYLLABUS

<u>First Semester</u>

		L	T	P	C
25MA605	**Advanced Engineering Mathematics**	3	0	3	4

Module-1
Linear Algebra:Linear dependence/independence of vectors, Rank of matrices, System of linearequations, Solution of system of linear equations, Vector spaces, Subspaces, Generating set, Basis,Dimension of vector spaces, Linear mapping, Transformation matrix, Basis change, Image andKernel of linear mapping, Affine spaces, Norm of a vector space, Dot product, Quadratic form,symmetric positive definite matrices, Length, angle and orthogonality, Orthonormal basis, Innerproduct of functions, Orthogonal projections, Gram Schmidt orthogonalization, Eigen values andvectors,Matrixdecomposition:Choleskydecomposition,Eigendecomposition,Singularvaluedecomposition,Matrixapproximation.

Module-2
Vectorcalculus:DifferentiationandTaylor'sseriesexpansionofunivariatefunctions,Partialdifferentiation, chain rule, Gradient of vector function(Jacobian), Gradient of a vectors with respectto a matrix, Identities for computing gradients, Back propagation and automatic differentiation,Gradientsindeepneuralnetworks,Higherorderpartialderivatives,Hessian,Taylor'sseries expansion of multivariate functions, Vector calculus for physical fieldproblems, divergence andcurl of vector fields, rotational and irrotational vector fields, Conservative vector fields, Vectorintegral calculus, line, surface and volume integrals, Stoke's theorem, Green's theorem and Gaussdivergencetheorem,
Probability: Introduction to Probability concepts, one dimensional and two dimensional Randomvariables,Jointly   DistributedRandomVariables,ConditionalDistributions.

Module-3
Solutionusingiterativemethods:GaussSeidel,SOR(pointandline),Conjugategradient,BiCGStab,GMRES, Solutionofsystemsofnonlinear algebraicequations.
Interpolations:Newton,Stirling,Lagrange,Richardson,QuadraticandCubicsplines,Inverseinterpolation.
NumericalDifferentiation;Numericalintegration:Higher-OrderNewton-Cotesformulas,Rombergintegration,multiple integrals.

<u>Lab Session</u>
- Verify vector dependence/independence, find rank, basis, dimension, eigenvalues/eigenvectors, and perform matrix decompositions (Cholesky, Eigen, SVD) using **MATLAB / Python with NumPy and SciPy**.
- Calculate gradients, Jacobians, Hessians, Taylor series expansions, and implement backpropagation and automatic differentiation using **MATLAB / PyTorch or TensorFlow in Python**.
- Solve linear and nonlinear equations using iterative methods like Gauss-Seidel, SOR, Conjugate Gradient, BiCGStab, and GMRES with **MATLAB / SciPy in Python**.

- Apply interpolation (Newton, Lagrange, Stirling, splines), numerical differentiation, and

integration (Newton-Cotes, Romberg, multiple integrals) using **MATLAB / SciPy in Python**.

TEXTBOOKS/REFERENCES

[1] AdvancedEngineeringMathematics–ErvinKreyszig,10thedition(2015),Wiely.

[2] Linearalgebra anditsapplication –GilbertStrang,5thedition(2018),Cengage Learning.

[3] MillerandFreund's-ProbabilityandStatisticsforEngineers–RichardAJohnson,7thedition(2008),Pearson.

[4] DifferentialequationswithapplicationsandHistoricalnotes-GeorgeFSimmons-TataMcGrawHill,3rdedition (2016),Taylor& Francis.

[5] MathematicsforMachineLearning–MarcPeterDeisenroth,A.AlsoFaisal,ChengSoonOng,Cambridge UniversityPress (2020)

[6] Machineleaning:Aprobabilisticperspective,KevinMurphy,MITPress(2012).

CourseOutcomes

CO1: Capability to understand mathematical notations and solve problems in linear algebra.CO2: Capability to do gradient evaluations of objective functions in optimization problemsCO3:Capabilityto do scalarand vector field operations
CO4:CapabilityforsolvingmathematicalequationsmodelledasdifferentialequationsCO5: Solveproblems indistribution ofrandom variablesandparameterestimation.

25TF601	AdvancedFluidDynamics	L	T	P	C
		2	1	0	3

Module-1
Review of Basic Concepts: Concept of continuum, types of fluid and fluid properties-Kinematics of fluid flow - Vorticity and circulation - Potential flows: velocity potential and stream function, flow nets- Ideal Fluid Flow Analysis: Two-dimensional flow in rectangular and polar coordinates-sources, sinks, doublets, flow over a circular cylinder, vortex flows.

Module-2
Reynolds Transport Theorem, Integral fluid flow analysis - Differential Fluid Flow Analysis: differential forms of mass, linear momentum, angular momentum and energy conservation equations. Navier-Stokes equations and exact solutions- Couette flow, Poiseuille flow, Hagen–Poiseuille flow. Approximate solutions: Creeping flow, inviscid flow, irrotational flow. Euler's equation for turbomachines, Introduction to various types of turbo machines.

Module-3
Boundary Layer Theory: Laminar Boundary Layer Equation, Two dimensional equations, dis-placement and momentum thickness, general properties of the boundary layer equations, Blasius solution. Von-Karman Momentum integral equation and skin friction drag. Turbulent Boundary Layer: Two-dimensional equation, Prandtl's mixing layer Karman's hypothesis universal velocity distribution, flow over a flat plate, skin friction drag.

TEXTBOOKS/REFERENCES

[1] Cengel,Y.A.andCimbala,J.M.FluidMechanics–Fundamentalsandapplications,TataMcGraw Hill, 4[th]Ed. 2019.

[2] MunsonB.R.,Young,D.F.,andOkiishi,T.H.,FundamentalsofFluidMechanics.7[th]Ed.,JohnWiley &Sons.2013.

[3] RichardJ.Glodstien,FluidMechanicsMeasurements,2ndEdition(2017),TaylorandFrancis.

[4] BernardSMassey,MechanicsofFluids,Taylor&Francis,9[th]Ed.,2019.

[5] S K Som., Gautam Biswas., and Suam Chakraborty, Introduction to Fluid Mechanics and Fluid machines, Mc Graw Hill, 3rd Edition.

[6] PNModi.,S.M.Seth.,HydraulicsandFluidMechanicsincludingHydraulicMachines,StandardBook House, 21st Ed, 2017.

[7] K Muralidhar G Biswas., Advanced Engineering Fluid Mechanics , Narosa publishers, 2nd Edition

[8] Pijush J Kundu, Ira M Cohen., Fluid Mechanics, Elsevier, 5th Edition, 2012.

CourseOutcomes

CO1: Developfundamentalknowledgeinthesubjectof fluidmechanics

CO2: Capabilitytoanalyzefluidflowsofdifferenttypesassociatedwithdifferentengineeringsituatio ns

CO3: Developskillto proposesolutionsto fluidflowproblems tocatertoindustrialneeds

CO4: Capabilitytoconduct researchactivitiesin theareaoffluidmechanics

25TF602	**AdvancedHeatTransfer**	L	T	P	C
		2	1	0	3

Module-1

Fourier's law, thermal conductivity of matter, heat diffusion equation for isotropic and anisotropicmedia, boundary and initial conditions. One-dimensional steady-state conduction through planewall, cylinder and sphere. Conduction with thermal energy generation, heat transfer from extendedsurfaces,radialfinsandfinoptimization;Multidimensional-steady-stateheatconduction;Transient conduction – lumped capacitance method and its validity, plane wall and radial systems,semi-infinite solid, anisotropic conduction. Review of viscous flow: Hydrodynamic and thermalboundary layers, Laminar flow heat transfer to developed and developing flow, laminar forcedconvectionin pipeand ducts with differentboundaryconditions, external flows.

Module-2

Turbulence modeling, Heat transfer in turbulent boundary layers, Eddy diffusivity of heat andmomentum, turbulent flow through circular tubes and parallel plates with heat transfer, analogiesbetweenheatandmomentumtransfer.Laminarnaturalconvection,naturalconvectioninenclos ures,heattransfercorrelations.Turbulentnaturalconvection,turbulentheattransfercorrelation,Practical applications.Boilingandcondensationheattransfer–correlationandapplications.   Heattransfer withphasechange:Poolboiling,   convectiveboiling,   filmanddropwisecondensation,   empirical relationsforheat transferwith phasechange.

Module-3

Heat Exchangers: Types, classifications, selection, standards, parallel, counter and mixed flow,multiple passes, LMTD, correction factors, effectiveness, NTU methods. Practical problems andexamples which covers the modelling of various heat transfer systems drawn from industrial fieldssuchas manufacturing, electronics, consumer products,and energysystems etc.

Radiation heat transfer, blackbody radiation, Plank distribution, Wien's displacement law, Stefan-Boltzmann law, surface emission, surface absorption, reflection, and transmission, Kirchoff's law,graysurface;Radiationintensityanditsrelationtoemission,irradiationandradiosity,Viewfactorsan dRadiationexchangebetweensurfaces. Elements of inverseheat transfer.

TEXTBOOKS/REFERENCES

[1]   BergmanT.L.,LavineA.S,IncroperaF.P,DeWittD.P.,FundamentalsofHeatandMassTransfer,Joh nWiley&Sons, 2011.
[2]   Holman,J.P.,"HeatTansfer",9thedn.TheMcGraw-HillCompanies,2008.
[3]   Burmeister,L.C.,ConvectiveHeatTransfer,2e,JohnWiley,1993.
[4]   ModestMF,RadiativeHeatTransfer,McGraw-Hill,1993.
[5]   JohnG.Collier, John R.Thome, Convectiveboilingandcondensation,Oxford UniversityPress,1996.
[6]   ShahRKandSekulicDP,FundamentalsofHeatExchangerDesign,JohnWileyandSons,2002.

CourseOutcomes

CO1**:**Deal withthe practicalsituations whichinvolveoneormorethanonemodesofheat transfer

CO2**:**Dealwithtransient andmulti-dimensionalconductionproblems

CO3**:**Analysethesituation includingfluid flowand heattransfer

CO4**:**Dealwiththeeffect ofradiationandheattransferassociatedwithitinpracticalsituations

CO5**:**Understand the concepts ofcondensation andboiling

CO6**:**Designheat exchangersusingLMTDand NTUmethods. Introductiontorefrigeration.

25TF603	AdvancedEngineeringThermodynamics	L	T	P	C
		2	1	0	3

Module-1

Reviewof   IandIILaws   ofThermodynamics,irreversibilityandavailability,conceptof entropyandentropygeneration,exergy.Maxwellequations,Joule-Thompsonexperiment.Thermodynamiccycles and cycle efficiency, exergy analysis of power and refrigeration cycles. New generation powerplants-Negativeemissionpower plants, Environmental impactof powerplants.

Module-2

Thermodynamic Properties of Homogeneous Mixtures: Partial molar properties, phase equilibrium,multi-component and multi-phase systems, equations of state, The van der Waals equation of state.Kinetic theory of gases, principle of equipartition of energy, collision cross section, mean free path.Statisticalthermodynamicsintroduction,energystatesand energylevels,macro andmicroscales.

Module-3

Thermodynamicsofreactivesystems:Firstandsecondlawanalysisofchemicalreactions,thermo-dynamicsof combustion, flames, adiabaticflametemperature.

Thermodynamics of irreversible processes: Phenomenological laws, reciprocity relation, applicability of the phenomenological relations, heat flux and entropy production, thermodynamic phenomena,thermoelectric phenomena.

Gasdynamics:Basicconcepts,EffectofMachnumberoncompressibility,IsentropicFlow,conceptsof Normal andobliqueshocks etc.

TEXTBOOKS/REFERENCES

[1] Bejan,A.,AdvancedEngineeringThermodynamics,3rdEd.,JohnWiley&Sons.2006
[2] CengelYunusA.andBolesMichael,Thermodynamics:AnEngineeringApproach,7thEdn,McGraw Hill, 2011.
[3] Winterbone,AliTuran,AdvancedThermodynamics forEngineers,ElsevierScience,2015.
[4] MichelASaad,Thermodynamics:PrinciplesandPractices,PrenticeHall,1997.
[5] F.W.Sears and G. L. Salinger, Thermodynamics, Kinetic Theory and StatisticalThermodynamics, NarosaPublishingHouse, New Delhi, 3rdedition, 1998
[6] StephenR.Turns,AnIntroductiontoCombustion:Concepts&Applications,McGraw-HillEducation,3rd Edition, 2012.

CourseOutcomes

CO1: Understand and apply the thermodynamic principles to reacting and non-reacting systems.

CO2: Understand the thermodynamic properties of homogeneous mixtures.

CO3: Understand the concept of kinetic theory and statistical thermodynamics.

CO4: Apply the thermodynamic principles to irreversible processes.

CO5: Analyse the performance of new generation power plant and fuel cell systems.

25TF604	**MachineLearning**	**L**	**T**	**P**	**C**
		3	**0**	**3**	**4**

Module-1

IntroductiontoMachineLearning–DataandFeatures–
MachineLearningPipeline:DataPreprocessing:Standardization,Normalization,Missingdataproblem,Data imbalanceproblem

Data visualization - Setting up training, development and test sets – Cross validation – Problem ofOverfitting,BiasvsVariance–Evaluationmeasures–
Differenttypesofmachinelearning:Supervisedlearning,Unsupervisedlearning,Reinforcementlearning,Ge nerativeLearningandadversariallearning.

Module-2
Supervised learning - Regression: Linear regression, logistic regression – Classification: K-
NearestNeighbor, Naïve Bayes, Decision Tree, Random Forest, Support Vector Machine, Perceptron, Erroranalysis.

Module-3
Unsupervised learning – Clustering: K-means, Hierarchical, Spectral, subspace clustering, GaussianMixtureModel,HiddenMarkovModel,ParameterEstimation:MLEandBayesianEstimate,Expect ation Maximization, Dimensionality Reduction Techniques, Principal component analysis,LinearDiscriminant Analysis.

Module-4
IntroductiontoNeuralNetworks,Reinforcementlearningandgenerativelearning.

Lab Session
- Perform data preprocessing (missing values, standardization, normalization, data imbalance) and data visualization; implement cross-validation using **Python with pandas, scikit-learn, and matplotlib**.
- Implement regression (linear, logistic) and classification (KNN, Naïve Bayes, Decision Tree, Random Forest, SVM, Perceptron) models with error analysis using **scikit-learn in Python**.
- Apply clustering (K-means, hierarchical, spectral), dimensionality reduction (PCA, LDA), and parameter estimation (MLE, Bayesian, EM for Gaussian Mixture Models) using **scikit-learn in Python**.
- Develop basic neural networks, reinforcement learning, and generative learning models using **TensorFlow or PyTorch in Python**.

TEXTBOOKS/REFERENCES

[1] AndrewNg,Machinelearningyearning,URL:http://www.mlyearning.org/(96)139(2017).

[2] KevinP.Murphey.MachineLearning,aprobabilisticperspective.TheMITPressCambridge,Massach usetts,2012.

[3] ChristopherMBishop.Pattern RecognitionandMachineLearning.Springer2010

[4] RichardO.Duda,PeterE.Hart,DavidG.Stork.PatternClassification.Wiley,SecondEdition;2007

[5] Sutton,RichardS.,andAndrewG.Barto.Reinforcementlearning:Anintroduction.MITpress,2018.

CourseOutcomes

CO1: Apply pre-processing techniques to prepare the data for machine learning

applicationsCO2:Implement supervised machinelearningalgorithms fordifferent datasets

CO3:Implement unsupervisedmachine learningalgorithms fordifferent datasets

CO4:Analyzethe errorto improvethe performanceof themachine learningmodels

25TF681	**ExperimentalMethods**	**L**	**T**	**P**	**C**
		0	**0**	**3**	**1**

EXPERIMENTS

1. a)Pipefrictionapparatus b)Reynoldsapparatus
2. a)Thermalconductivityofsolidsb)Heattransfer throughpin fin
3. a)Notchapparatusb) Peltonwheeltestrig
4. a)Forced convectionheattransferb)Naturalconvectionheattransfer
5. a)Verificationof Bernoulliequationb)Centrifugalpump testrig
6. a)Parallel&counterflowheatexchangerb)Shellandtube heatexchanger
7. a)Meta-centreapparatusb) Venturiand orificemetertestrig
8. a)Stephan-Boltzmannapparatusb)Emissivityapparatus
9. a)Francisturbinetestrigb)Hele-Shawflowapparatus
10. R&ACtestrig.

TEXTBOOKS/REFERENCES

[1]   Goldstein,R.J.,FluidMechanicsMeasurements,2ndEd.,CRCPress.2017.
[2]   Eckert,R.G.andGoldstein,R.J.,MeasurementsinHeatTransfer,2ndEd.,Springer.1986.
[3]   ExperimentalMethodsforEngineersbyHolman,8thEdition(2012),McGrawHill.

CourseOutcomes

CO1: Gain confidence and develop physical insight into the fundamental concepts in fluids
andthermalengineering

CO2: Identifying sources of errors in experiments and estimate

uncertaintyCO3:Understand and utilizecurvefittingtechniques.

25RM609	**ResearchMethodology**	**L**	**T**	**P**	**C**
		2	**0**	**0**	**2**

Module1
Meaning of Research, Types of Research, Research Process, Problem definition, Objectives of Re-search, Research Questions, Research design, Approaches to Research, Quantitative vs. QualitativeApproach, Understanding Theory, Building and Validating Theoretical Models, Exploratory vs.Confirmatory Research,Experimental vs Theoretical Research,Importance of reasoning in research.

Problem Formulation, Understanding Modeling& Simulation, Conducting Literature Review, Referencing, Information Sources, Information Retrieval, Role of libraries in Information Retrieval,Toolsforidentifyingliteratures,Indexing and abstractingservices, Citation indexes.

Module2
Experimental Research: Cause effect relationship, Development of Hypothesis, Measurement Systems Analysis, Error Propagation, Validity of experiments, Statistical Design of Experiments, FieldExperiments,Data/VariableTypes&Classification,Datacollection,NumericalandGraphicalData Analysis:Sampling,Observation,Surveys, InferentialStatistics,and InterpretationofResults.

Module3
Preparation of Dissertation and Research Papers, Tables and illustrations, Guidelines for writing theabstract,introduction,methodology,resultsanddiscussion,conclusionsectionsof amanuscript.
References, Citation and listing system of documents Intellectual property rights (IPR) - patents-copyrights-Trademarks-Industrial design geographical indication. Ethics of Research-ScientificMisconduct- Forms of Scientific Misconduct. Plagiarism, Unscientific practices in thesis work, Ethicsin science.

TEXTBOOKS/REFERENCES
[1]   Bordens, K. S. and Abbott, B. B., "Research Design and Methods – A Process Approach", 8thEdition,McGraw-Hill, 2011.
[2]   C.R.Kothari,"ResearchMethodology–MethodsandTechniques",2ndEdition,NewAgeInternationalPublishers.
[3]   Davis,M.,DavisK.,andDunaganM.,"ScientificPapersandPresentations",3rdEdition,Elsevier Inc.
[4]   MichaelP.Marder,"ResearchMethodsforScience",CambridgeUniversityPress,2011.
[5]   T.Ramappa,"IntellectualPropertyRightsUnderWTO",S.Chand,2008.
[6]   RobertP.Merges,PeterS.Menell,MarkA.Lemley,"IntellectualPropertyinNewTechnologicalAge ",AspenLaw& Business, 6 editionJuly2012.

CourseOutcomes

CO1:Todefineresearch,methodologyandstepsinvolved inresearch.
CO2:Tolearntodefineaproblem,andresearchhypothesis.Tounderstandtheimportanceofliteraturesurvey,gaps and challenges.
CO3:Tolearnthebasicconceptsofresearchdesign,sampling,modeling&simulationandunderstandthe importanceofcitation, H-index, Scopus.
CO4:Tolearntowritetechnicalreport,paperandthesis.
CO5:To knowabout intellectualpropertyrights, ethicsin researchand plagiarism.

SecondSemester

25TF611	ComputationalFluidDynamicsandHeatTransfer	L	T	P	C
		3	0	3	4

Module1

Review of Conservation equations for mass, momentum and energy; Equations in rectangular,cylindrical and spherical coordinate systems; Eulerian and Lagrangian approach, Conservative andnon-conservativeforms of theequations, rotatingco-ordinates.

ClassificationofsystemofPDEs:parabolicellipticandhyperbolic;Boundaryandinitialconditions;

Numerical Grid Generation: Basic ideas, transformation and mapping, unstructured grid generation,hybridgrids,movinggrids,unmatchedmeshes,CGNSnotationforgridanddata,mesh-freecalculations.

Module2

Finite Volume Method: Basic methodology, finite volume discretization, approximation of surfaceand volume integrals, interpolation methods - Central, Upwind, Hybrid, Power Law and QUICKformulationsand comparison forconvection-diffusionproblem;

TVDschemes, Fluxlimiterfunctions;

AdvancedFiniteVolumemethods:FVdiscretizationintwoandthreedimensions,SIMPLEalgorithm and flow field calculations, variants of SIMPLE- SIMPLER, SIMPLEC; PISO andPIMPLEalgorithms.

Module3

Turbulence and turbulence modeling, Introduction to turbulence modeling, Reynolds stress, RANSmodel, one-, two- and multiple equations for turbulence modeling; Reynolds Stress TransportModel;LargeEddySimulation,DetachedEddySimulationandDirectNumericalSimulationmethods;Illustrativeflowcomputations usingCFDcodes.

CFDmethodsforcompressibleandhigh-speedflows;reactingflows.

Finite element methods: Introduction to Finite Element Analysis, formulation of finite elementmethodsforheattransferinsolids,formulationoffiniteelementmethodsforfluidflows:Incompressibleflows,Navier-Stokes equationsincludingheattransfer.

Formulation for fluid-structure interactions:Moving mesh and adaptive mesh, acoustic fluidscoupledto structures,Navier-Stokes fluids coupled tostructures

Commercialsoftware–gridgeneration,flowpredictionandpost-processing.ValidationmethodsforCFDanalysis.

Introduction to open source CFD packages and solution to practical problems, Introduction toturbulencemodels.

Lab Session

- Solving 1D and 2D heat diffusion problem without heat generation using finite volume techniques using Python/Matlab.
- Solving 1D and 2D heat diffusion problem with heat generation using finite volume techniques using Python/Matlab.
- Solving unsteady 1D heat diffusion problem without heat generation using finite volume techniques using Python/Matlab.
- Simulate 2D incompressible laminar flow through a rectangular channel. Determine the

velocity profile at various locations and compare with the analytical parabolic profile for Poiseuille flow using Ansys Fluent/OpenFOAM.

TEXTBOOKS/REFERENCES

[1] Versteeg,H.andMalalasekra,M.,AnIntroductiontoComputationalFluidDynamics:TheFiniteVolumeMethod,2nd Ed.,PrenticeHall. 2007

[2] DaleAnderson,JohnC.Tannehill,RichardH.Pletcher,RamakanthMunipalli,VijayaShankar,ComputationalFluidMechanicsandHeatTransfer,4th Ed.CRCPress,2021.

[3] Hirsch,AnalysisofInternalandexternalflows,Vols1,2.Wiley-Jnterscience,2007

[4] Jaluria,Y.,andTorrance,K.E.,ComputationalHeatTransfer,Taylor&Francis.2002.

[5] Ferziger,JoelH.,Peric,Milovan,Street,RobertL,ComputationalMethodsforFluidDynamics,4th Ed. Springer. 2020.

[6] Bathe,K.J.FiniteElementProcedures.2nd Ed.Klaus-JurgenBathe,MIT,2014.

Courseoutcomes

CO1:Familiarizationwithconversationequationsindifferentformsandabilitytoclassifyasystem ofPDEs.
CO2: Apply FVM techniques for diffusion and convection-diffusion problems.
CO3:Understandandapplydifferentpressure-velocitycouplingforincompressibleflows.
CO4:Numericalmodellingofturbulenceandabilitytochoosethemostoptimumonefora problem.
CO5: Solution of compressible fluid flows and its applications.CO6:Usageofcommercial andopen sourceCFDcodes.

25TF612	IntroductiontoDeepLearning	L	T	P	C
		3	0	3	4

Module-1
DeepNeuralNetworks(DNN)–ConvolutionalNeuralNetwork(CNN)–RecurrentNeuralNetwork(RNN):Long-Short-Term-Memory(LSTM)-Graphbased NeuralNetwork(GNN)

Module-2
Pre-processing:NoiseRemovalusingdeeplearningalgorithms-FeatureExtraction-SignalAnalysis:Time Series Analysis, CNNs, Auto encoders.

Module-3
ImageAnalysis:TransferLearning,Attentionmodels-EnsembleMethodsforSignalandImageAnalysis.

TEXTBOOKS/REFERENCES

[1] BishopC.M,"PatternRecognitionandMachine Learning",Springer,1stEdition,2006.

[2] Goodfellow I, Bengio Y, Courville A, & Bengio Y, "Deep learning", Cambridge: MIT Press, 1stEdition, 2016.

[3] SomanK.P,Ramanathan.R,"DigitalSignalandImageProcessing–TheSparseWay",Elsevier,

1stEdition, 2012.

CourseOutcomes

CO1:Applythefundamentals ofdeep learning.

CO2: Apply deep learning algorithms using

Matlab/Python.CO3: Applydeep learningmodels for signal

analysis.

CO4: Implementdeeplearningmodelsforimageanalysis.

<u>**Lab Session**</u>
- Build DNN, CNN, RNN, and LSTM models using **TensorFlow or PyTorch (Python)**.
- Develop GNN models using **PyTorch Geometric or TensorFlow with Spektral (Python)**.
- Perform signal preprocessing, feature extraction, and time series analysis with CNNs and Autoencoders using **TensorFlow/Keras (Python)**.
- Apply transfer learning, attention models, and ensemble methods for image and signal analysis using **TensorFlow or PyTorch (Python)**.

25TF613	**AutomationandIoT**	**L**	**T**	**P**	**C**
		3	**0**	**0**	**3**

Module-1

FundamentalsofMeasurementSystems,InstrumentTypesandPerformanceCharacteristics,sources of error, classification and elimination of error. Signal Conditioning.Data acquisition.Probes. Sensors - Pressure, Flow,Level, Temperature

Introduction to control systems – open and closed loop control systems – Modeling of simplemechanical and electrical systems – transfer functions. Time response characteristics of controlsystems, Stability analysis of control systems, Frequency Response, Introduction to PI, PD and PIDcontrollers,Design ofaPIDcontroller

Module-2

IntroductiontoAutomation-Automatedmanufacturingsystems.SensorsandActuatorsinAutomation - Digital and analog sensors; Fluid power actuators; Control valves; Electrical systemelements;Motors drives; Mechanical devices.

PneumaticandHydraulicSystems-Pneumaticfundamentals-controlelements,positionandpressure sensing – logic circuits - switching circuits - sequential circuits - cascade method. ControlUsingPLCs-Relaylogic;Combinationalandsequentialcontrol,Sequentialflowchart,Minimization of logic equations; Ladder logic diagrams; Programmable logic controllers (PLCs);PLC components; Programming; I/O addresses; Timer and counters; A/D conversion and sampling;PLCapplications.

Module-3

Industry 4.0 &IoT: Introduction. Digitization, Drivers of Industry 4.0, End-to-end digital integrationwithin a smart factory, IOT Swarm Sensors, RF and wireless sensors module, power

managementmodule;Challenges.

Internet of Things (IoT): Introduction, Physical system, Cyber-Physical Systems, IoT Architectures.Applications: Smart cities & smart homes, connected vehicles, IoT for temperature dependentcooling system, engine management system, machine condition monitoring and health caremonitoring.

.

TEXTBOOKS/REFERENCES

[1] Doebelin's E.O., and Manik D.N., "Doebelin's Measurement Systems", 6th Edition, McGraw Hill Education, 2011
[2] Katsuhiko Ogata, "Modern Control Engineering", 5th Edition, Pearson Education, NewDelhi,2010
[3] AntonyEspossito,"FluidpowerwithApplications ",Pearson,SixthEdition.,2003.
[4] Raj, Pethuru, and Anupama C. Raman.The Internet of things: Enabling technologies, plat-forms,and usecases. Auerbach Publications, 2017.
[5] MikellP.Groover,"Automation,ProductionSystemsandComputerIntegratedManufactur-ing",Third Edition, PearsonEducation, 2009.
[6] Frank D. Petruzella, *Programming Logic Controllers*, 5th Edition, 2017, McGraw Hill Book Company.

CourseOutcomes

CO1**:**   Selectandusevariousmeasuringinstrumentsfor apractical application

CO2**:**   Design controllersbasedonstabilityandperformancerequirements

CO3**:**   Designpneumaticandhydrauliccircuits

CO4**:**   ProgramPLCforagivenapplication

CO5   ApplyIOTtodifferentapplications

25TF699	ProjectSeminar	L	T	P	C
		0	0	3	1

This seminar forms the pre-runner to the final year project in which students are expected to do athorough literature survey and formulate a research problem on the broad topic given by the faculty.Students shall extensively study the research already carried out on the seminar topic. They shallbring out the current status of the problem, clearly indicating the shortcomings and gaps in theinvestigation carried out so far. 3

Evaluation
Students shall prepare a properly formatted seminar report giving allof the above details. They need to present the work carried out at the end of the semester. Creditswill be awarded based on the viva-voce during the presentation and the content and organization ofthereport.

CourseOutcomes

CO1:   Identifyappropriatejournals/conferencesrelatedtoatopicofresearchinterestand conductliteraturereview

CO2:   Developawarenessof therecenttrends inthetopicofinvestigation

CO3:   Write technical reports in prescribed formats
CO4:   Identify research gaps and formulate valid research problem worthy of publishing in reputed journals

25TF682	Advanced Thermal & Fluids Eng. Lab	L	T	P	C
		1	0	3	2

Dynamic similarity and scaling; Types of measurement devices & techniques; Errors in Measurement and its Analysis: Causes and types of experimental errors, systematic and random errors; Uncertainty analysis, computation of overall uncertainty, calibration.

Experiments in Wind Tunnel: Surface pressure distribution on circular cylinder, symmetric and cambered aero-foils-estimation lift and drag, smoke flow visualization. Laminar turbulent transition for various geometries.

Experiments in Water Channel: Visualization of flow over streamline and bluff bodies vortex shedding from bluff bodies (like circular cylinder)-study of vortex streets.

2-D laminar flow over bluff bodies (Hele-Shaw flow)-construction of flow net (velocity potential lines and streamlines). Numerical visualization of flow over bluff bodies using Ansys/Algor Software-comparison of numerical flow patterns with experimental ones.

Performance characteristics of Centrifugal compressor and axial flow fan.

Free Convection Heat Transfer-Forced Convection Heat Transfer-Measuring instruments for R&A/C applications-measurement of very low temperature-Measurement of density and viscosity of oils-measurement of gas flow rate through pipelines.

Steady state and transient convective heat transfer.

Radiation Heat Transfer - Boiling Heat Transfer-Performance evaluation of vapour compression refrigeration-performance evaluation of thermoelectric refrigerator and heat pump-Measurement and analysis of combustion parameters in I.C. Engines-Evaluation of the calorific value of gaseous and liquid fuels.

Experiments in supersonic jet: static pressure distribution in the nozzle wall, estimation of Mach number.

Experiments in pneumatic and hydraulic systems

TEXTBOOKS/REFERENCES

[1]   Goldstein, R.J., Fluid Mechanics Measurement, 2nd Ed., CRC Press. 2017.
[2]   Doeblin, E.O., Measurements System Application and Design, 5th Ed., McGraw Hill, 2004
[3]   Marangoni RD and Lienhard JH, Mechanical Measurements by Beckwith TG, 6th Ed., Prentice Hall. 2006
[4]   Eckert, R.G. and Goldstein, R.J., Measurements in Heat Transfer, 2nd Ed., Springer. 1986.
[5]   Barlow Jewel B., Rae William H., Pope Alan, Low speed wind tunnel testing, 3e, Wiley, 1999.

Course Outcomes

CO1:   Develop physical insight into the advanced concepts in fluids and thermal engineering.
CO2:   Design experiments to estimate physical variables involved in fluid flow and heat transfer.
CO3:
CO4:

		L	T	P	C
25TF698	**Industry Internship**	0	0	2	1

Students shall visit industrial units connected with their curriculum and conduct a detailed study onthermo-fluid systems pertinent to the industry visited and present reports. They are encouraged tosolveapractical problemrelated to theindustry. At the end of the training student should submit a report and certificate of completion to the department in the prescribed format.

Evaluation

This course is mandatory. The student shall make a report. The committee constituted by the department will assess the student based on the report submitted

CourseOutcomes

CO1: Familiarize with the industry environment/Research Laboratory
CO2: Understand the application of theoretical concepts in a practical setting.
CO3: Prepare technical documents/presentations related to the work completed

ThirdSemester

		L	T	P	C
25TF798	**Dissertation–StageI**	**0**	**0**	**22**	**11**

Dissertation (stage-1) should be based on the area in whichthe candidate has undertaken thedissertation work as perthe common instructions for all branches of M.Tech. The examinationshall consistof the preparation ofreportconsisting ofa detailed problem statement, literaturereview and. initial results of the problem. The work has to be presented in front of the examinersconsisting of Head of the Department and PG coordinator/Faculty Advisor and other invited facultymembers (if any). The candidate has to be in regular contact with his guide and the topicofdissertation must be mutuallydecided bytheguideand student.

CourseOutcomes

CO1: Identifyappropriate methodologyto solve aresearch problem
CO2: Executetheirresearchinvestigationadoptingthechosenmethodologyandobtainre-sults
CO3: Writeatechnical reportinaprescribedformat.

FourthSemester

		L	T	P	C
25TF799	**Dissertation–StageII**	**0**	**0**	**30**	**15**

Dissertation(Stage-2)willstartinsemesterIVwhichisexpectedtobeacontinuationofDissertation-1. In this phase of the project, students are expected to do the remaining part of theirworksdoneinstage-1.Toparticularlynote,thisphaseoftheprojectinvolvesdetaileddataacquisition and subsequent analysis of the research problem. The dissertation should be presented instandard formatasprovidedby thedepartment/guide.Thecandidatehastopreparea detailedprojectreportconsistingofintroductionoftheproblem,problemstatement,literaturereview,object ives of the work, details of methodology adopted (experimental/numerical/analytical) andresults and discussion. The report must bring out the conclusions of the work and future scope forstudy. The work has to be presented before the panel of examiners consisting of an approvedexternalexaminer,internalexaminer/guideasdecidedbythedepartmentheadandPGcoordinator /faculty advisor. The candidate has to be in regular contact with his/her guide throughouttheprojectduration.Allthestudentsareexpectedtopublishtheirworksinreputedjournals/confe rences(Scopus-indexed).

CourseOutcomes

CO1: Carry out detailed analysis of research data acquired through experi-

mental/numerical/analyticalmethodologiesinthecontextoftheexisting literatureand drawvalidconclusionsthereof.

CO2: Writetheprojectreportsystematicallyinaprescribedformat.

CO3: Writeresearcharticlesworthyofpublishinginreputedjournals/conferences(SCI-indexed/Scopus-indexed)

ELECTIVES(I&II)

FluidStream

		L	T	P	C
25TF631	**Aerodynamics**	3	0	0	3

Module-1

Basics equations of Fluid Mechanics, Potential flows, Stream function, Velocity potential, Two-dimensional incompressible flows: Laplace's equation, its solutions, Elementary potential flows,Superpositionprinciple,thecombinationofelementarypotentialflows,conformalmapping.Implementationofconformalmappingtextbookproblemswiththehelpofpython/Matlabprogramming.

Module-2

Boundarylayer:LaminarandTurbulentboundarylayers:characteristicsandfactorscausingseparation, Effect of boundary layer separation on flow over airfoils. Introduction to bluff bodyaerodynamics: flow over circular cylinders, effect of Reynolds number and geometry, dynamiceffects. vortex shedding: modes and mechanisms, Strouhal number, aerodynamic coefficients, span-wisecorrelation.Implementingtheconceptsinreal-lifeaerodynamicproblemsusingCFDsimulationsor experimental techniques.

Module-3

Flowsoveraerofoils:Conformaltransformation,thinairfoiltheory,forcesonairfoils,Kuttacondition,Generationofcirculation,LiftofZhukhovskyairfoil.Introductiontofinitewings:Prandtl's lifting line theory. Propulsion of fishes and flight of birds. Experimental aerodynamics:flowvisualizationtechniques–PIV,LDV,HydrogenBubbleVisualization,othertechniques.Measurements–PIV,Hotwireanemometer,Cobraprobe,Pressuretransducers,forcebalances.

TEXTBOOKS/REFERENCES

[1] AndersonJ.D.FundamentalsofAerodynamics,McGraw-Hill,2017.
[2] McCormickB.K.Aerodynamics,AeronauticsandFlightMechanics,JohnWileyandSonInc.,1994.
[3] Zdravkovich,M.M.,1997.FlowAroundCircularCylinders,Vol.1:Fundamentals.OxfordUniversityPress,Oxford, England.
[4] Zdravkovich,M.M.,2003.FlowAroundCircularCylinders,Vol.2:Applications.OxfordUniversityPress,Oxford, England.
[5] Schlichting,H.andGersten,K.,BoundaryLayerTheory,Springer-Verlag,2004.
[6] FluidMechanicsMeasurements,RichardJ.Glodstien.,2ndEdition(2017),TaylorandFrancis.

CourseOutcomes

CO1**:**Developmentofinsightintothefundamentalconceptsandwritetheequationsgoverningthefluid flow.

CO2**:**Gaining**c**onceptualunderstandingofStreamfunction,velocitypotentialsolutionstoLaplace'sequation and to knowtheconditions under which potential-flow theoryhold.

CO3**:**Skilltousesuperpositiontobuildsimplepotentialflowsandtounderstandtheconceptofconformalmapping and its applications.

CO4**:**Acquiringknowledgeonaerofoilnomenclature&characteristicsandthePrandtl'sliftinglinetheoryand to do practicalproblems based on this theory.

CO5**:**BecomeKnowledgeableofbluffbodyaerodynamics:flowseparation,unsteadywakecharacteristics,experimental andnumerical methodsto investigate bluffbodyproblems.

25TF632	**Biofluidmechanics**	**L**	**T**	**P**	**C**
		3	**0**	**0**	**3**

Module-1

Review of Concepts in Fluid Mechanics, Kinematics, Hydrostatics, Conservation relations, ViscousFlow,UnsteadyFlow; Reviewof Concepts inSolid Mechanics.
Heart: Anatomy, Cardiac cycle, circulatory systems, pressure, flow chamber volume and work,CardiacMuscle,HeartSounds,Coronary
Circulation,CardiacConduction,ECGandWiggersdiagram.
Hemodynamics: Hematology and Blood Rheology, Composition of Blood, Viscosity of Blood,Constitutive equations, Power Law Model, Herschel-Bulkley Model, Casson Model, Fahraeus andFahraeus–LindqvistEffects, Effectiveviscosity.
Arterial system: Structure of Arteries, Venous System Physiology, Venous Pump, Mechanics ofArterialWalls, Compliance.

Module-2

MacrocirculationSystem:SystemicandPulmonarycirculations,Arteries,Veins,VascularBifurcations and Branches, Blood Flow through Curved Vessels. Steady Blood Flow, Applicationsof Bernoulli equation, Arterial Stenosis, Arterial Aneurysm, Cerebral Aneurysm, Cardiac ValveStenosis, Applications of Poiseuilli's Law, Gorlin equation, Fluid friction, Rigid Tube Flow Models,Entrance Length, Transition Reynolds number, Casson model steady blood flow. Unsteady bloodflow, Windkessel model, Continuum Models for Pulsatile Flow Dynamics, Wave Propagation in theArterial System; Pulsatile Flow in Rigid Tubes: Wormersley Solution, Fry Solution; HemodynamicTheories of Atherogenesis, Flow through Curved Arteries, Bifurcations, Stenoses and Aneurysms;Effect of Viscoelasticity of Tube Material; Flow in Collapsible Tubes, Turbulence, Instability
inPulsatileFlow.MicrocirculationSystem:Bloodflowinsmallvessels,Arterioles,Capillaries,interstitialfluidflow;Venules,MassTransportinTissue,Kroghmodelofoxygendiffusion,Porosity, Tortuosity and Permeability, Governing Equations in Porous Media, Fluid Transport inPoroelasticMedia,BioheatTransfer.

Module-3

BiofluidDynamicsinHumanOrgans:LungandRespiratorySystem,Kidney,Liver,Brain,IntraocularSystem, EndocrineSystem Biofluids.
NativeHeartValves:AorticandPulmonaryValves,MitralandTricuspidValves.
Biofluid Flow in Artificial, Assistive and Implantable Devices, Lumped Parameter MathematicalModels.ComputationalFluidDynamicAnalysisoftheHumanCirculation:ModellingConsiderations for Biofluid Mechanical Simulations, Generation of grid from scanned images, CFDSimulations in the Human Circulation, Multiscale Modelling. Fluid Structure Interaction Modelling,FutureDirections ofBiofluid Mechanics.

TEXTBOOKS/REFERENCES

[1] KrishnanB.Chandran,StanleyE.Rittgers,AjitP.Yoganathan,BiofluidMechanics:TheHumanCirculation, 2e,CRC Press, 2012.
[2] NihatOzkaya,MargaretaNordin,"FundamentalsofBiomechanics:Equilibrium,Motion,andDeformation",Springer,3rdEdition,Verlag,2012.
[3] DavidARubenstein,WeiYinandMaryDFrame,BiofluidMechanics,AcademicPress(Elsevier), 2013
[4] C.RossEthierandCraiggA.Simmons,IntroductoryBiomechanics,CambridgetextsinBiomedicalEngineering,2007.
[5] C.Kleinstreuer,BiofluidDynamics:PrinciplesandApplications,CRCPress,Taylor&FrancisGroup, 2006.
[6] Y Cengel and J Cimbala, Fluid Mechanics: Fundamentals and Applications, 4e, McGraw-Hill,2018.

CourseOutcomes

CO1:Fluid and solid mechanics that are pertinent to blood flow in the heart and blood
vessels.CO2:Hematology,BloodRheologyandmodelsforViscosityofBlood,StructureofArteriesand Veins.
CO3:MicrocirculationSystem,interstitialfluidflow,massandheattransportbiofluidDynamicsinHuman Organs,
CO4:AnalysisofbloodflowinNativeHeartValvesandImplantableDevices
CO5:ComputationalFluidDynamicAnalysisoftheHumanCirculationFluidStructureInteractionModelling

		L	T	P	C
25TF633	**BoundaryLayerTheory**	**3**	**0**	**0**	**3**

Module-1

Introduction: Ideal and real fluids, Boundary-Layer concept, Laminar boundary layer, turbulentboundary layer, Separation of boundary layer, Navier- Stokes equations, Laminar Boundary LayerEquation:Twodimensionalequations,displacementandmomentumthickness,generalpropertiesof theboundarylayer equations, wall friction, dragand lift.

Module-2

Boundary layer on an airfoil. Boundary layer control, Continuous suction and blowing. Solution ofthe boundary layer equation (Plane flows): Similarity Solutions, Boundary layer with and withoutouter flow, moving plate, Wedge flow, Free jet, Flows in straight channel. Approximate Methods,Momentum-Integralmethods. Numericalintegrationofboundarylayer equations.

Module-3

Turbulent Boundary Layer: Mean motion and fluctuations, Equations for turbulent flows, Prandtl'smixing layer Karman's hypothesis. Thermal Boundary Layers: Effect of Prandtl Number, Similarsolution of thermal boundary layer, Integral method for computing heat transfer, Coupling of thevelocity field to the temperature field. Boundary layer in non-Newtonian flows, Boundary layer inMagnetohydrodynamics.

Separation in adverse pressure gradients. Concept of and occurrence in steady flows, and at rearstagnationpointofimpulsivelystartedcylinder.Formofskinfrictionnearseparationpoint:Goldsteinsi ngularity.

Introductiontointeractiveboundarylayers.Goldsteinnearwake.Trailing-edgetripledeck.

TEXTBOOKS/REFERENCES

[1] Schlichting,H.andGersten,K.,BoundaryLayerTheory,Springer-Verlag,2004

[2] White,F.M.,ViscousFlow,3rdEd.,McGrawHill.2005

[3] O.A.OleinikandV.M.Samokhin,MathematicalModelsinBoundaryLayerTheory,CRCPress,199 9

[4] Cebeci,T.andCousteix,J.,ModelingandComputationofBoundary-LayerFlows,2ndEd., Springer-Verlag.2005

[5] Rozenhead,L., LaminarBoundaryLayers,DoverPublications,1988

[6] Kays,W.M.,Crawford,M.E.,andWeigand,B.,ConvectiveHeatandMassTransfer,4thEd.,McGraw Hill. 2004

CourseOutcomes

CO1:Understandtheconceptofhydrodynamicboundarylayerandderivetheboundarylayerequations.

CO2:Identifytheeffectivemethodforboundarylayercontrolandapplytheappropriatemethodforoptimize d design.

CO3:Understandthe concept ofthermalboundarylayer and itscontrol.

25TF634	**FluidStructureInteraction**	L	T	P	C
		3	0	0	3

Module-1

Introduction to bluff body flows: factors influencing bluff body flows – boundary layer – flow separation – wake formation-vortex shedding. Flow over stationary isolated circular cylinder: classification of flow regimes based on Re – Laminar states of flow – steady laminar wake- periodic laminarregime, Turbulent states of flow: Transition in wake (TrW) – Transition in shear layers (TrSL) –Transition in boundary layers (TrBL) – Fully Turbulent flow state (T). Vortex shedding: Strouhalnumber-mechanism-span wise correlation – vortex street formation- mathematical models. Inducedforces (lift and drag): effect of Re- flow incidence angle-body surface texture- blockage-free streamturbulence.

Flowovernon-circularcylinders–InfluenceofgeometryandRe-flowseparation-wakestructures – vortexsheddingandinducedforces.FSIinbiologicalsystems:bloodflowthrougharteriesandveins-diagnosisof diseases.

Module-2

Flow interference between two circular cylinders – tandem, side-by-side and staggered arrangements - classification of interference regimes – effect of spacing - flow patterns and surface pressure distribution - biased gap flow - induced forces (lift & drag. Flow over cylinder clusters (multiplecylinders).

Flow interference between non-circular cylinders - influence of Re - body geometry – spacing – differencesandsimilaritieswith circular cylinders.

Module-3

Flow-induced vibrations (FIV): Influencing factors – body geometry-reduced velocity - free streamturbulence – flow incidence – mass ratio – damping – added mass. Vortex-induced vibration-galloping-flutter-fluid elastic excitation-turbulence buffeting-other types. Flow structures aroundoscillating cylinders-induced forces and cylinder response-equations of motion-modal analysis, In-terferenceeffects inFIV.

Some practical problems: Tube bundle vibrations in heat exchangers and nuclear reactors- Vibrations of stacks and other tall structures, transmission line vibrations. Passive and active control ofFIV. Energy extraction from FIV. FIV in Engineering Codes. Experimental measurements, flowvisualizationtechniques

TEXTBOOKS/REFERENCES

[1]   RobertD.Blevins,Flow-InducedVibration,2ndEdition,VanNostrandReinhold,NewYork,USA, 1990.

[2] E.Naudascher,andD.Rockwell,Flow-InducedVibrations:AnEngineeringGuide,Doverpublishers,USA, 2005.

[3] M.M.Zdravkovich,Flowaroundcircularcylinders,Vol.1:Fundamentals,OxfordUniversityPress, Oxford, England.1997.

[4] M.M.Zdravkovich,Flowaroundcircularcylinders,Vol.2:Applications,OxfordUniversityPress,Oxford, England.1997.

[5] Thomson,W.TandDahleh,M.D.,TheoryofvibrationswithApplications,PrenticeHall,1997.

[6] Rao,S.S.,MechanicalVibrations,PearsonEducation,2004.

CourseOutcomes

CO1: Developfundamental knowledgein FSI

CO2: Developmentofcapabilitytoanalysefluidflowsofdifferenttypesassociatedwithdifferentengineeringsituations involvingFSI

CO3: Developskillto proposesolutions toFSIproblemsandcaterto industrialneeds

CO4: AcademiccapabilitytoconductresearchactivitiesintheareaofFSI.

25TF635	**IntroductiontoTurbulence**	L	T	P	C
		3	0	0	3

Module-1

Origin, examples and character of turbulence, Reynolds stress, energy relations, closure problem,phenomenology, eddy viscosity. Statistics, Spectra, space-time correlations, macro &micro scales,statistical theory of turbulence, locally isotropic turbulence, Kolmogorov's hypothesis, correlationmethod,spectral method,turbulencediffusion.

Module-2

Numerical Turbulence modelling: Reynolds averaging technique, Reynolds stress, RANS model,one-, two- and multiple equations for turbulence modelling, Spalart-Allmaras model, k-epsilonmodels, k-omega models, SST k-omega models and RSM. Introduction to Large eddy simulation(LES) and Direct Numerical Simulation (DNS) method. Implementation and verification of thedifferentturbulent modelsin real-lifeturbulent flowproblems usingCFD software.

Module-3

Experimental techniques: Hot Wire Anemometer, Laser Doppler Anemometer, Flow visualizationtechniques,laminar-turbulent transition. Relaminarization.

TEXTBOOKS/REFERENCES

[1] TennekesH.andLumleyJ.L.,AfirstcourseinTurbulence,MITPress,USA,1972.

[2] Stephen.B.Pope,TurbulentFlows,CambridgeUniversityPress,UK,2000.

[3] Davidson P.A., Turbulence: An introduction for Scientists and Engineers, Oxford University Press Inc, New York, 2004.

[4] Batchelor G.K., The Theory of homogeneous turbulence, Cambridge University Press, UK, 1993.

[5] Schlichting, H., and Gersten, K., 2000, Boundary Layer Theory, Springer.

[6] Wilcox, D.C., 2010, Turbulence Modelling for CFD, DCW Industries, California, USA.

Course Outcomes

CO1: To understand the concept and origin of turbulence and the fundamental characteris-tics of turbulent flows

CO2: The study the concept of closure problem, energy spectra, eddy viscosity, Reynolds stress etc.

CO3: To understand the concept of statistical turbulence, Kolmogorov's hypothesis, space-time correlation methods, spectral methods etc.

CO4: To understand concept time, space and ensemble averaging, Numerical Turbulence modelling, one-, two- and multiple equations for turbulence modelling, RSM, LES and DNS methods

CO5: To study experimental measurement of turbulence such as hotwire anemometer, laser Doppler anemometer etc.

Thermal Stream Electives

25TF641	Computational methods for Micro and Nano Scale Thermal Systems	L	T	P	C
		3	0	0	3

Module-1

Introduction: Computational simulation, need for discrete computation.

Classical Mechanics: Mechanics of Particles, D'Alembert's principle and Lagrange's equation, variational principles, Hamilton's principle, conservation theorems and symmetry properties, central force problems, virial theorem.

Module-2

Statistical Mechanics: Review of probability and statistics, quantum states of a system, equations of state, canonical and microcanonical ensemble, partition function, energy levels for molecules, equipartition theorem, minimizing the free energy, partition function for identical particles, Maxwell distribution of molecular speeds.

Module-3

Moleculardynamics:basicmachinery,running,measuring,andanalyzing,interatomicpotentials,LAMMPS, Examples.
Introduction
toMultiscalemethodsandapplications.IntroductiontoDatadrivenm odelingandscientificcomputation.

TEXTBOOKS/REFERENCES

[1] Bird,G.A.,MolecularGasDynamicsandtheDirectSimulationofGasFlows,OxfordSciencePublica tions, 1994.

[2] Goldstein,H.,Poole,C.,andSafko,J.,ClassicalMechanics,3rdEdn.,PearsonEducation,2006.

[3] Bowley,R.,andSanches,M.,IntroductoryStatisticalMechanics,2ndEdn.,OxfordSciencePublicati ons,2007.

[4] Ercolessi,F.,A
MolecularDynamicsPrimer,NotesofSpringCollegeinComputationalPhysics,ICTP,Trieste,June 1997.

[5] Liu,WingKam,Karpov,E.G.,andPark,H.S.,NanomechanicsandMaterials,JohnWiley&Sons, 2006.

[6] Robert,K.,Ian,H.,Mark,G.,NanoscaleScienceandTechnology,JohnWiley&Sons,2005.

[7] Groot,R.D.,andWarren,P.B.,Dissipativeparticledynamics:BridgingtheGapbetweenAtomistican d Mesoscopic Simulation,J. Chem. Phys, 107, 4423 (1997).

CourseOutcomes

CO1:Togainknowledgeonfundamentaltopicslikeclassicalmechanicsandstatisticalmechanics.CO2:H aveexposureabout atomisticsimulationtechniques and its applications.

CO3: Develop molecular dynamics simulations for a given application using

LAMMPSCO4:Haveexposureabout multiscale simulationmethods.

CO5:Applydatadrivensciencetechniquesforanalysisanddesign.

25TF642	Cryogenics	L	T	P	C
		3	0	0	3

Module-1

Introduction to Cryogenic Systems: Historical development, Applications of Cryogenics (Space,Food Processing, Superconductivity, Electrical Power, Biology, Medicine, Electronics and CuttingToolIndustry).

Low Temperature Properties: Properties of Engineering Materials (Mechanical properties, Thermalproperties,Electric andMagneticproperties), Properties ofCryogenic fluids.

Module-2

Introduction to Liquefaction Systems: Ideal system, Liquefaction systems for Neon, Hydrogen andHelium.Criticalcomponentsofliquefactionsystems,JouleThomsonexpansion,Adiabaticexpansion, LindeHampsonCycle,Claude&CascadedSystem.IntroductiontoCryogenicRefrigerationSystems: MagneticCooling,StirlingCycle, CryoCoolers.

Module-3

CryogenicFluidStorageandTransferSystems:Cryogenicstoragevesselsandtransportation.Thermal insulation and their performance at cryogenic temperatures, Super insulations, Vacuuminsulation, Powder insulation. Thermal stratification, Cryogenic fluid transfer systems. Cryogenicengine injectors (subcritical & super critical) Cryogenic Instrumentation: Pressure, flow-rate, liquid-level and temperature measurements. Types of Heat Exchangers used in cryogenic systems. CryoPumpingApplications.

TEXTBOOKS/REFERENCES

[1]   Willaim.E.Bryson,Cryogenics,HanserGardnerPublications,1999.
[2]   JhaA.R.,CryogenicTechnologyandApplications,ElsevierButterworth-Heinemann,USA,2006.
[3]   Thomas.M.Flynn,CryogenicEngineering,MarcelDekkerInc.,2005.
[4]   Randell.F.Barron,CryogenicSystems,OxfordUniversityPress,NewYork,1985.
[5]   StoeckerW.F.andJonesJW,RefrigerationandAirConditioning,2ndEd.,McGraw-HillInternationalEditions, 1982.
[6]   KlausD.TimmerhausandThomasM.Flynn,CryogenicProcessEngineering,PlenumPress,NewYork,1989.

CourseOutcomes
CO1: Understand properties of material at cryogenic temperatures.CO2:Knowabout various liquefaction systems
CO3:Getideasoncryogenicrefrigerationsystems,cryogenicinstrumentationandcryogenicheatexchangers

		L	**T**	**P**	**C**
25TF643	**HeatExchangeEquipment**	**3**	**0**	**0**	**3**

Module-1

Introduction: Classification of heatexchangers,designof heatexchangers: engineering design-steps for designing, design a workable system, optimum systems, economics, probabilistic approachto design, sizing and rating problems; LMTD and ε-NTU approach of design. Introduction to designcodes(ASME, TEMA, HTRIetc)

Design of double pipe heatexchangers: introduction, basic design procedure and theory, overallheat transfer coefficient, fouling factors , fins, weighted fin efficiency, pressure drop analysis, de-signproblems.Introduction tothreefluid/ multifluid heat exchangerbehaviour.

Design of shell and tube heat exchangers – basic design procedure and theory, shell and tubeexchangers: construction details, general design considerations: fluid allocation, shell and tube fluidvelocities, tube-sideandshell side heat-transfer coefficient andpressure drop, Kern'smethod,designproblems.

Module-2

Design of Condenser; Heat-transfer fundamentals, Condensation of steam, Condensation inside andoutside horizontal tubes, Condensation inside and outside vertical tubes, De-superheating and sub-cooling,Pressuredropincondensers, design problems.

Design of Compact heat exchanger: introduction, design procedure of compact heat exchanger,pressure drop analysis of plate fin heat exchanger, problems. Plate heat exchanger: Gasketed plateheat exchangers, Welded plate, advantages and disadvantages over the other heat exchangers, de-sign procedure, heat transfer coefficient and pressure drop calculation on both the sides of exchang-er,problems on plateexchanger.

Module-3

Thermal design of heat exchanger such as Regenerative heat exchanger, Super heater, Air pre-heaters,analysis and design ofcoolingtowers.

Heat pipe: introduction, working principle, working fluids, wick structure and material, classifica-tion of heat pipe, pressure variation along the heat pipe, limitations of a heat pipe, problems on heatpipe.

TEXTBOOKS/REFERENCES

[1]   Serth.R.W, ProcessHeatTransfer-PrinciplesandApplications,Elsevier,2007.
[2]   KernD,Q,ProcessHeatTransfer,McGraw-Hill,1965.
[3]   ShahRKandSekulicDP,FundamentalsofHeatExchangerDesign,JohnWileyandSons,2002.
[4]   Coulson&Richardson'sseries,SinnottR.K.,ChemicalEngineeringDesign,Elsevier,2005
[5]   KaysWMand LondonAL,CompactHeatExchanger,KriegerPublishingCompany,1998

CourseOutcomes

CO1**:** Background, Application, Classification and Common terminologies of Heat

exchangersCO2**:**Design of Tubular Heat Exchangers

CO3**:** Design of Regenerative and Compact Heat

exchangersCO4**:**Design concepts ofHeat Pipes.

25TF644	HVACandRefrigeration	L	T	P	C
		3	0	0	3

Module-1

History of refrigeration, Refrigeration cycles: vapour compression cycle and vapour absorptionsystems.Thermodynamicanalysisofcycles.Systemcomponents:RefrigerantCompressors-Reciprocating, Hermetic, Rotary, Centrifugal Scroll Compressors -Comparison, Construction andOperation characteristics. Evaporators- DX coil, flooded type Chillers, Condensing Units andCoolingTowers.

Module-2

Refrigerants:Desirableproperties,Classification,Designation,AlternateRefrigerants,GlobalWarming Potential & Ozone Depleting Potential aspects. Expansion devices: Automatic ExpansionValves, Capillary Tube & Thermostatic Expansion Valves. Cycling controls and system balancing:Pressure and Temperature controls, Range and Differential settings. Selection and balancing of sys-temcomponents -Graphical method**.**

Module-3

Psychrometry: Moist air behaviour - Psychometric chart - Different Psychometric process and theiranalysis. Air conditioning: Summer and Winter Air conditioning - Cooling Load Calculations - AirDistribution Patterns - Dynamic and Frictional Losses in Air Ducts - Equal Friction Method - FanCharacteristicsin Duct Systems.

TEXTBOOKS/REFERENCES

[1]   RameshChandraArora.RefrigerationandAirConditioning,Prentice HallIndia,2015.
[2]   StockerW.F.andJonesJ.W.Refrigeration&AirConditioning - McGrawHill,1985.
[3]   DossatR.J.PrinciplesofRefrigeration,JohnWiley,1989.
[4]   GoshnayW.B.PrinciplesandRefrigeration,CambridgeUniversityPress,1982.

CourseOutcomes

CO1**:** Identifythesuitabilityof refrigeration systems

CO2**:**Selectrefrigerantsandcomponentslikeevaporator,compressor,condenser,expansiondevic-esetc.

       based on operational characteristics

CO3**:**Designofrefrigerationandair-

conditioningsystemsusingfundamentalsofheatandmasstransferprinciples

CO4**:** Evaluate the performance of an air-conditioning

systemCO5**:**Estimatecooling/heatingload forgivenapplication

25TF645	ICEngineSystems,CombustionandEmissions	L	T	P	C
		3	0	0	3

Module-1

Constructional features of different types of internal combustion engines, SI Engine introduction,carburetion mixture requirements, Fuel supply. Thermo-chemistry and thermodynamics of combus-tion, Laminar and turbulent premixed flames, Premixed engine combustion, Ignition, Stages ofcombustion,Normalandabnormal combustion,factorsaffectingknock, Combustionchambers.

Module-2

CI engine, Injection Systems, Spray formation and atomization, Combustion systems and manage-ment, Mechanical and electronic-Combustion in CI engines-stages of combustion-Factors affectingcombustion, Direct and indirect injection systems. Introduction to Turbo charging and supercharg-ing. Basic concepts of engine simulation, governing equations, simulation of various engine pro-cessesfor SIand CIEngines. Alternatefuels forSIand CIengines.

Module-3

Chemicalequilibriumanalysis(BOLandEOL), ApplicationofNACA–CEAcode.

Introduction to air pollutants and pollution; Genesis and formation of engine emissions, NO kinet-ics, Soot formation and oxidation, NOx-Soot trade off. Control of emissions in SI and CI engines,Impactofenginedesignparametersonemissions,exhaustaftertreatment, leande-NOxcatalysts.

TEXTBOOKS/REFERENCES

[1]   StephenR.Turns,AnIntroductiontoCombustionConceptsandApplications,McGrawHillInternationalEdition, 2012.
[2]   V.Ganesan,InternalCombustionEngines,TataMcGrawHillEducation(India),2012.
[3]   FergusonC.R.,KirkpatrickA.T.,Internal.CombustionEngines:AppliedThermosciences,2ndEdition,JohnWiley&Sons, 2001.
[4]   WillardW.Pulkrabek,EngineeringFundamentalsoftheInternalCombustionEngine,PearsonPrentice-Hall,2004.
[5]   PundirB.P.,EngineEmissions:PollutantFormationandAdvancesinControlTechnology,NarosaPublishingHouse, NewDelhi, 2007.
[6]   GuptaH.N.,Fundamentalsof InternalCombustionEngines,PHILearningPvt.Ltd.,2006.

CourseOutcomes

CO1:Understandtheconstructionalfeaturesandsystemsofdifferenttypesofinternalcombustionengines.

CO2:Understand basic concepts of engine simulation and performance optimization.CO3:Tofamiliarizethemechanismofcombustion,pollutantformationanditsc ontrol.

25TF646	InverseHeatTransfer	L	T	P	C
		3	0	0	3

Module-1

Inverse heat transfer problem concept, Convexand non-convexfunctions, Fundamentals of natureof solutions of mathematical models, Well and ill-posed problems, Regularization, Conditionalprobability,Baye's theorem,conditionalindependence,Naïve Bayes.

Module-2

Linear and non-linear optimisation problems, Parameter estimation, Gradient descend methods,Levenberg-Marquard method, Conjugate gradient method, Adjoint problem. Review of governingequations of heat transfer and fluid flow problems, inverse problems, examples, Methods of designofexperiments
DifferentialEvolutionTechniques'(geneticalgorithm based).

Module-3

Deterministic, heuristic, and hybrid methods for Single-Objective optimization and response surfacegeneration, Adjoint methods, Bayesian approaches for the solution of inverse problems, Low-ordermodels and their use for solving inverse boundary problems, Data, Noise, and Model reduction ininverseproblems,Applications.

TEXTBOOKS/REFERENCES

[1] Ozisik,M.N.andOrlande,H.R,Inverseheattransfer:fundamentalsandapplications.CRCpress,202 1

[2] AfshinJ.Ghajar,ThermalMeasurementsandInverseTechniques,CRCpress,2011

[3] Orlande,HelcioRB., Inverseheattransfer:fundamentalsandapplications. CRCPress,2021

[4] Beck,JamesVere,andKennethJ.Arnold.Parameterestimationinengineeringandscience.JamesBe ck, 1977.

CourseOutcomes

CO1:Capabilityto understand mathematical backgroundofinverseproblems.

CO2:Capability to understand the nature of mathematical models and methods to solve themCO3:Capabilitytoconvertparameter estimationproblemsintooptimizationproblems andsolve them.

CO4:Capability to formulate inverse problems in heat transfer and select appropriate method tosolve.

CO5:Capabilityofidentifyresearchproblems indesignofsystems involvingheat transfer.

25TF647	MicroandNanoScaleThermalEngineering	L	T	P	C
		3	0	0	3

Module1

Physicsofminiaturisation–scalinglaws.

MicroscaleEnergyTransportinSolids:Microstructureofsolids,crystalvibrationsandphonons,photoninteractions, particle transport theories, non-equilibrium energytransfer.

MolecularForcesandPhaseChangeinThinLiquidFilms:Thermodynamicsofthinfilms,interfacialmeniscus properties, interfacial mass flux.

Heat Transfer and Pressure Drops in Microchannels: Single phase and two phase flow, flow boiling,dryout,bubblebehaviour, flow pattern.

Module2

Microfluidics:Introduction,continuumassumption,pressuredrivenmicroflows,boundaryconditionin fluid mechanics, surfacetension driven flows, Electrokinetic Flows.

Nanofluidics:SimpleFluidsinNanochannels,Waterinnanochannels,nanofluidicenergyconversion.

Module3

MicroHeatPipes:Fundamentaloperatingprinciples,steadystateandtransientmodelingandconstructiontechniques.

Microscale Thermal Sensors and Actuators: MEMS technology, flow sensors, infrared radiationdetectors,thermalconductivitysensor,thermalexpansionactuatorsandmicro-steamengine.Nanofluids:Preparationofnano-fluids,sputtering,characterizationofnano-fluids,thermalpropertiesofnano-fluids,singlephaseconvectiveandboilingheat transfer processes.

Drugdelivery,labon chipdevices,BioMEMS.

TEXTBOOKS/REFERENCES

[1] Nam-TrungNguyen,StevenT.Wereley,SeyedAliMousaviShaegh,FundamentalsandApplicationsofMicrofluidics, 3rd Ed.,Artech House,2019.

[2] Tien, C. L ., Majumdar, A. and Gerner, F. M., Microscale Energy Transport, Taylor & Francis,2003.

[3] Karniadakis,G.,Beskok,A.,andAluru,N.,MicroflowsandNanoflows:FundamentalsandSimulation, Springer, 2005.

[4] CBSobhan,GPPeterson,MicroscaleandNanoscaleHeatTransfer-FundamentalsandEngineeringApplications,TaylorandFrancis/CRC, 2008.

[5] Satish,K.,Srinivas,G.,Dongqing,L.,Stephane,C.,andMichaelR.K.,HeatTransferandFluidFlowin MinichannelsandMicrochannels, FirstEdition,Elsevier, 2005.

[6] Kirby, B.J., Micro- and Nanoscale Fluid Mechanics: Transport in MicrofluidicDevices,Cambridge UniversityPress,2010

CourseOutcomes

CO1:Tofamiliarisewiththescalingofforceswithsystemsizeandtheassociatedchangesinthephysicalbehavior ofmicro/nano scalesystems.

CO2:Togainafundementalunderstandingaboutthethermaltransportinmicro/nanoscalesystems.

CO3:Tofamiliarisewithmethodsusedforanalysingfluidtransportinmicro/nanoscalesystems.

CO4:Toidentify,formulate,andsolveinterdisciplinaryproblemsrelevantformicroandnanoscalethermal and fluid systems.

25TF648	Two-phaseFlowandHeatTransfer	L	T	P	C
		3	0	0	3

Module-1

Introduction to phase change flow and heat transfer technology, Various industrial applications,Review of one-dimensional conservation equations in single phase flows, Types of flow, volumetricconcentration, void fraction, volumetric flux, relative velocity, drift velocity, flow regimes, flowpatternmaps, analytical models.

Interfacialtension,wettingphenomenonandcontactangles,Phasestabilityandnucleation.

HomogeneousFlow:Onedimensionalsteadyhomogeneousequilibriumflow,homogeneousfrictionfactor, turbulentflow friction factor.

Module-2

Separated Flow: Slip, Lockhart-Martinelli method for pressure drop calculation, pressure drop forflowwithboiling, flowwithphasechange.

Drift Flow Model: General theory, gravity flows with no wall shear, correction to simple theory,Armondor Bankoff flowparameters.

Boiling: Thermodynamics of boiling, Regimes of boiling, nucleation and dynamics of bubbles, gasnucleation in bulk liquid, growth of bubbles, motion at a heating surface, heat transfer rates in poolboiling, critical heat flux in pool boiling, forced convection boiling, critical heat flux in forcedconvectionboiling,minimumheatflux,filmboiling,postdryoutheattransfer,heattransfercorrelations,boilingofmetals.Flow instabilities,chokingintwo-phaseflow.

Module-3

Condensation:Nuathalttheory,Filmanddrop-wisecondensation,boundarylayertreatmentoflaminar film condensation, condensation in vertical and horizontal tubes, condensation inside ahorizontal tube.

SignalAnalysis, Two Fluid-PopulationBalanceTechnique, Volume ofFluid Method,Lattice-BoltzmannModel, Smoothed Particle Hydrodynamics.

MolecularDynamics:Boiling,Condensation,Solid-LiquidFlow,Gas-Solid-Flow.

TEXTBOOKS/REFERENCES

[1] Ishii,M.andHibiki,T.,Thermo-fluidDynamicsofTwo-PhaseFlow,Springer.2009.

[2] Collier,J.G.andThome,J.R.,ConvectiveBoilingandCondensation,OxfordUniversityPress,1996

[3] Brennen,C.E.,FundamentalsofMultiphaseFlow,CambridgeUniversityPress.2009.

[4] Tong,L.S.andTang,Y.S.,BoilingHeatTransferandTwo-phaseFlow,2ndEd.,CRCPress.1997.

[5] Ghiaasiaan,S.M.,Two-Phaseflow,Boiling,andCondensation",2ndedition,2017, CambridgeUniversityPress

[6] GrahamBWallis,Onedimensionaltwophaseflow,McGrawHill,1969.

CourseOutcomes

CO1:Describethemostimportantphenomenaandprinciplesoftwo-phaseflowinengineeringapplications

CO2:Applythebasictwo-phasemodelsandflowpatternmapstocalculatethepressuredropsoftwo-phaseflowat various conditions.

CO3:Explainthemainpointsofboilingandcondensation,heattransfer,andtheirenhancementmethods

CO4:Describethe conceptboilingcrisis(e.g.,DNB- departurefromnucleate boiling,anddryout)andits modelling

CO5:Applythemodelsofcriticalflowandfloodingtoanalyzelimitingflowofengineeringprocesses.

CO6:Understandthecurrentstatustowriteascientificreviewforatopicinthefieldoftwo-phaseflow and heat transfer and identifyproblemforresearch

Automation/EnergySystemsElectives

		L	T	P	C
25TF651	**FuelCellTechnologyandHydrogenEnergy**	**3**	**0**	**0**	**3**

Module-1

Overview of Fuel Cells, Fuel Cell performance. Low and high temperature fuel cells, Polymerelectrolyte fuel cells, Alkaline fuel cells, Phosphoric fuel cells, Molten carbonate fuel cells, Solidoxide fuel cells, Fuel Cell thermodynamics, Fuel Cell Efficiency, Fuel Cell Electrochemistry, Fuelcell reaction kinetics- electrode kinetics, CurrentPotential Relationship, Sensitivity of Parametersinpolarization curve.

Module-2

Cell components, Materials Properties and Process: Membrane, Electrode, Gas Diffusion Layer,Bipolar Plates. Fuel cell Operating Conditions: Operating Pressure and Temperature, Reactant flowrates. Fuel Cell Mass and Energy Balance. Fuel Cell Modelling: Conservation of Mass, Momentum,Energy, Species and Charge. Sizing of Fuel Cell Stack, Stack configuration, Fuel cell systems andSamplecalculations.

Module-3

Hydrogen as a source of energy, physical and chemical properties, suitability of hydrogen as a fuel,salientcharacteristics, relevant issues and concerns.

Production of hydrogen, thermal-Steam reformation, gasification and woody biomass conversion,partial oxidation methods, biological hydrogen production, photo dissociation, direct thermal or cat-alyticsplittingofwater.

General storage methods, compressed storage-composite cylinders, metal hydride storage, carbonbasedmaterials forhydrogenstorage. Safetyaspectsof hydrogen storageand handling.

TEXTBOOKS/REFERENCES

[1] AndrewL.Dicks,DavidA.J.Rand,FuelCellSystemsExplained,ThirdEdition,JohnWiley&SonsLt d, 2018
[2] FranoBarbir,PEMFuelCell:TheoryandPractice,AcademicPress, ElsevierInc,2012
[3] Bent Sorensen, Hydrogen and Fuel Cells Emerging Technologies and Applications, AcademicPress,ElsevierScience,2012
[4] BusbyRL,HydrogenandFuelCells:AComprehensive Guide,PennWellBooks(2005).
[5] GuptaR.B.(2008);HydrogenFuel:Production,TransportandStorage,CRCPress
[6] TomorrowsEnergy:Hydrogen,Fuelcellsandtheprospectsforacleanerplanet,PeterHoffman,TheM ITPress,Cambridge,London,England.

CourseOutcomes

CO1: Understand and apply the basic thermodynamic and electrochemistry to fuel cell

systems.CO2:Understandthe effectof operatingconditions onthe performanceofthefuel cell.

CO3:Studentsabletounderstandanddemonstratethehydrogenproductiontechnologies,storagemethodsand strategies for transition tohydrogen economy.

		L	**T**	**P**	**C**
25TF652	**InstrumentationandProcessControl**	**3**	**0**	**0**	**3**

Module-1

Instrumentation: Introduction:Measurementanditsclassificationbyphysicalcharacteristics,directand inferential measurement,on-and off- linemeasurement.

StaticCharacteristicsofInstruments:Error,accuracy,repeatability,drift,threshold,backlash,hysteresis, zero-stability, static, coulomb and viscous friction, live zero, suppressed zero, workingbind.

Sensor and Transducers: Classification, principles and applications, interpretation of performancespecificationoftransducers.

Building Blocks of an Instrument: Transducer, amplifier, signal conditioner, signal isolation, signaltransmitter,display,data acquisitionmodules,I/O devices,interfaces.Process

Instrumentation: Working principles of transducers/instruments employed for the measurement offlow,level,pressure,temperature,density,viscosity, etc.andtheirmeritsanddemerits.

Module-2

Data Acquisition and Signal Processing: Systems for data acquisition and processing, modules andcomputerized data system, digitization rate, time and frequency domain representation of signals,andNyquistcriterion;Introductionto LabView andMatlabfordatacapture andanalysis.

Process Control: Introduction: The concept of process dynamics and control, review of Laplacetransformmethods,Laplacetransformofdisturbancesandbuildingfunctions,dynamicmodelbuil dingof simplesystems.

Linear Open Loop System: Physical examples of first order systems and their response for step,impulse and sinusoidal inputs, linearization of nonlinear models, response of first order system inseries,examplesofsecond order systemsand theirresponse.

Linear Closed Loop System: The control system and its elements, closed loop transfer functions,transient response of simple control systems, concept of stability and use of Routh-Hurwitz test forstability.

Module-3

Controllers:Modesofcontrolaction,control systemanditsclosed-looptransfer function.

RootLocusMethod:Rootlocustreatment,responsefromrootlocusanditsapplicationtocontrolsystemdesign.

FrequencyResponse:Introductiontofrequencyresponse,Bodediagramsofsimplesystems,Bodestabilitycrit erion,Controlsystemdesignbyfrequencyresponse,useofgainandphasemargins.

Modelpredictivecontrol,BatchProcesscontrol,Plant-widecontrol&monitoring,Plant-widecontrol design, Instrumentation for process monitoring, Statistical process control, Introduction toFuzzy Logic in Process Control, Introduction to OPC, Introduction to environmental issues andsustainabledevelopmentrelatingto processindustries.

ProcessAutomation,Roleofdigitalcomputersysteminprocesscontrol,Distributedinstrumentationand control system,PLC,DCS, SCADA.

TEXTBOOKS/REFERENCES

[1] Ramesh C Panda and T. Thyagarajan, An Introduction to Processmodelling,Identificationandcontrol forEngineers,NarosaPublishingHouse, 2017.

[2] NakraB.C.andChaudhry K.K.,Instrumentation,MeasurementandAnalysis,2ndEd.,Tata-McGrawHill.2004

[3] AndrewW.G.,AppliedInstrumentationintheProcessIndustries,Vol.I,IIandIII3rdEd., GulfPublication.1993

[4] DonaldR.Coughanowr,ProcessSystemsAnalysisandControl,ThirdEdition,McGrawHillInc.,2013.

[5] DaleE.Seborg,DuncanA.Mellichamp,ThomasF.EdgarandFrancisJ.DoyleProcessDynamicsand Control, JohnWileyandSons, 2010.

[6] BequetteB.W.,ProcessControl–Modeling,DesignandSimulation,Prentice-HallofIndia.2003

CourseOutcomes

CO1:Understand basic principles and importance of process control in industrial process plants.CO2:Studyand estimatevarious characteristics ofinstruments
CO3:AnalyseanddesignLinearOpenandClosed LoopSystems

CO4:Controllers and Modes of control actionCO5:Plant-widemonitoring & control
CO6:ProcessAutomation andDistributedinstrumentationandcontrolsystem..

25TF653	**Introductiontodata-drivenmethods**	**L**	**T**	**P**	**C**
		3	**0**	**0**	**3**

Module-1

Implementation of Linear Systems Revisited: Direct Solution Methods, Iterative Solution Methods,Gradient(Steepest)Descent,Eigenvalues,EigenvectorsandSolvability,NonlinearSystems.
Curvefitting:Least-SquareFittingMethods,PolynomialFitsandSplines.SingularValueDecomposition: Basics, Principal Component Analysis (PCA), Diagonalization, Proper orthogonalModes.
DimensionalityReduction:PODforPartialdifferentialequations,PODexpansion,PODwithsymmetries.

Module-2

Dynamic mode decomposition (DMD): Introduction, Dynamics of DMD versus POD, ApplicationsofDMD.
Dataassimilation:Introductionandapplications.
Equation free modelling: Multiscale physics, Lifting and Restricting in Equation- Free

Computing.Module-3

Applications of POD and DMD for Thermal and Fluid systems: Introduction to coherent structures,Turbulence, Jet flows, boundary layer, flows in complex geometries, flows in internal combustionengines.

TEXTBOOKS/REFERENCES

[1] Kutz,J.N.,Brunton,S.,Brunton,B.,andProctor,J.,DatadrivenModelingandScientificComputation: MethodforComplexSystemsandBigData. OxfordUniversityPress,2013.

[2] Kutz,J.N.,Brunton,S.,DatadrivenScienceandEngineering:MachineLearning,DynamicalSystemsa nd Control. CambridgeUniversityPress, 2019.

[3] Holmes,P.,Lumley,J.L.,Berkooz,G.,andRowley,C.W.,Turbulence,CoherentStructures,Dynamic alSystemsandSymmetry.CambridgeUniversityPress,2012.

[4] Kutz,J.N.,Brunton,S.,Brunton,B.,andProctor,J.,DynamicModeDecomposition:DataDrivenMode lingof ComplexSystems.SIAM,2016.

[5] Anton,H.,andRorres,C.,ElementaryLinearAlgebra.JohnWiley&SonsInc.2005.

Courseoutcomes

CO1**:**Togainfundamentalknowledgeonthebasicconceptsandtheoreticalideasindata-driventechniquesin thecontext ofprogramminglanguageinfrastructure.

CO2**:**Todevelopanunderstandingofthe algorithmsusedfor transformingandreducingdata.

CO3**:**Toimplementthevarioustheoreticalandcomputationaltoolsonscientificapplicationsrelevantf or thermal and fluid systems.

25TF654	MachineLearningandArtificialIntelligence	L	T	P	C
		3	0	0	3

Module-1

Mathematical concept review: Linear algebra and Probability, Introduction to Machine learning,Terminologies in machine learning, Types of machine learning, Linear Regression, MultivariateRegression,Bias Variance,Classification of Linear models, BayesianClassifiers.

Module-2

Regularization, Hyper-parameter Tuning,Subset selection, shrinkage method, DimensionalityReduction,Evaluationmeasures,Decisiontrees,Ensemblemodels–BaggingandBoosting,RandomForest.

Module-3

Support Vector Machines - Large margin classifiers, Nonlinear SVM, kernel functions Hyperplane,Perceptron Learning, Unsupervised Learning Algorithms: Dimensionality Reduction-PrincipalComponent Analysis (PCA), Clustering – Hierarchical, Partitioned clustering: K-means, Basics ofNeuralNetwork.

TEXTBOOKS/REFERENCES

[1] GilbertStrang, Linear Algebraandlearningfrom data,Wellesley,Cambridgepress,2019.

[2] KevinMurphy,MachineLearning:AProbabilisticPerspective,MITPress2012

[3] TomMitchell,Machine Learning,McGraw Hill,1997

[4] G.James, R.Tibshirani,AnIntroductionto StatisticalLearning:with applicationsinR,Spring-er.

[5] T. Hastie, R. Tibshirani,Elements of StatisticalLearning: Data mining,Inferenceand Predic-tionSpringer.

[6] AndreasMullerandSarahGuido,IntroductiontoMachineLearningwithPython:AGuideforDataScientists, Shroff/O'Reilly, 2016.

CO1**:**Developa good understandingoffundamental principlesofmachine

learning.CO2**:**FormulationofaMachineLearningproblem.

CO3**:**Develop   a   model   using   supervised/unsupervised   machine   learning   algorithms forclassification/prediction/clustering.

CO4**:**Evaluateperformanceofvariousmachinelearningalgorithmsonvariousdatasetsofadomain.

CO5**:**DesignandConcreteimplementationsofvariousmachinelearningalgorithmstosolveagivenproblem usinglanguagessuchasPython.

25TF655	**NuclearReactorThermal-HydraulicsandSafety**	L	T	P	C
		3	0	0	3

Module1

Basic   concepts   of   reactor   physics,   radioactivity.   Neutron   Scattering.   Thermal   and   fast reactors.Overview of nuclear reactor systems. Sources and distribution of thermal loads in nuclear powerreactors.

Flow   Regimes   in   Two-Phase   Flow,   Two-phase   flow   models: Homogeneous   Equilibrium Model,Separated and Slip Flow Model, Void Fraction Correlations, Stratified Flow Analysis and FlowPattern transition, Pool Boiling & Flow Boiling Heat Transfer, Critical Flow, Nuclear ApplicationsofFluid MechanicsandHeatTransfer.

Module2

Heat   generation   in   fuel,   coolant,   structural   and   shield   materials   and   decay   heat,   Nuclear HeatTransport,   steady   and   unsteady   conduction   in   fuel,   cladding,   and   structural   materials elements,Multi-dimensionalthermal-hydraulicsin plenum.

Hydraulicsofreactorsystemloops,Hydraulicsofheatedchannels.

Thermalstratification,thermalshock,thermalfatigue,gasentrainment,steam-liquiddropletseparation.

Safety   philosophy,   Thermal   Design   Principles,   Single   Channel   Analysis,   Sub-channel analysis,LOCA and LOFA Modelling, modelling of containment loading. Waste management. Indian nuclearpowerprogram.

Module3

NuclearInstrumentation,HealthPhysics,RadiationShielding.

ReviewofThermal-HydraulicsCodesUsedforReactorAccidentAnalysis,AdvancedSafetyConceptsand UpcomingReactor SafetyMethodsand next generationreactors.

Thermal-Hydraulics Uncertainty Analysis, Probabilistic safety assessment, regulatory procedureandlicensing.

TEXTBOOKS/REFERENCES

[1] Todreas,NeilE.,andMujidS.Kazimi.NuclearSystemsVolume1:ThermalHydraulicFun-damentals.2nd ed. CRC Press, 2011.

[2] Glasstone,S.andSesonske,A.,NuclearReactorEngineering,4thEdn.Vol.1(2001)Vol.2(2004),CBS Publishers &Distributors

[3] VaidyanathanG.,NuclearReactorEngineering(PrinciplesandConcepts),SChand&Compa-ny,2013.

[4] Lamarsh,J.R.andBaratta,A.J.,IntroductiontoNuclearEngineering,3rdEdn,PrenticeHall,2001.

[5] LewisE.E.,NuclearreactorSafety,WileyInterscience,1977.

[6] TongL.S.   andTangY.S.,BoilingheattransferandTwo-phaseFlow,TaylorandFrancis,1997.

CourseOutcomes

CO1**:**ApplicationofreactorphysicsconceptsandworkingofthermalandfastreactorsCO2**:**Un derstanding of two-phase flows, boiling, condensation, Critical Heat FluxCO3**:**Heatgeneration and transportinreactor CO4**:**ThermalhydraulicphenomenainsidereactorvesselandcomponentsCO5**:**Safet yprinciples&safetyevaluation andLicencingaspects CO6**:**AnalysisofTransientandAccidents

	L	T	P	C
25TF656 **PowerPlantandThermalSystemsEngineering**	3	0	0	3

Module-1

Introduction & Economics: Energy scenario, Overview power plants, Types of power stations,Economy and thermal schemes of power stations. Review of various ideal cycles–Rankine andBrayton–and fuel-air cycles. Thermodynamics optimization of design parameters. Load curves, var-ious terms and factors involved in power plant calculations. Effect of variable load on power plantoperation, Selection ofpower plant units. Economics of plant selection, other considerations inplantselection.

Module-2

Coal based plants: Analysis of steam cycles, Feedwater heaters, Deaerator and drain cooler, Opti-mization of cycle parameters, reheat and regeneration, Analysis of multi-fluid coupled cycles, Co-generation of power and process heat. Thermal power plant equipment, Combustion mechanisms,Furnaces, Combustion control, boilers (coal based, RDF based), economizers, Feedwater treatment,feed water heater, Boiler maintenance, ash handling system, Dust collection system Operation andmaintenance of steam power plant,heat balance and efficiency, Site selection of a steam powerplant

Gas turbine plants: Layout of gas turbine power plant, Elements of gas turbine power plants, Gasturbine fuels, cogeneration, auxiliary systems such as fuel, controls and lubrication, operation andmaintenance,Combined cycle powerplants, Siteselection of gas turbinepower plant.

Module-3

Diesel based plants: General layout, Components of Diesel power plant, Performance of dieselpower plant, fuel system, lubrication system, air intake and admission system, supercharging sys-tem, exhaust system, diesel plant operation and efficiency, heat balance, Site selection of dieselpowerplant, Comparativestudyof diesel power plant with steampower plant.

Nuclear based plants: Elements of nuclear power plants, nuclear reactors and fuels. New generationpowerplants.

Renewable energy: solar, geothermal, wind, biomass, ocean, fuel cells, Environmental aspects ofpower generation, sustainabilityand futurescenarios.

Negative emission power plants: Introduction, thermodynamics, carbon capture and utilization,techno-economicaspects.

TEXTBOOKS/REFERENCES

[1] PowerPlantEngineering,P.K.Nag,McGraw-HillEducation
[2] PowerPlantTechnology,M.M.El-Wakil,McGraw-HillEducation
[3] GasTurbines byV Ganeshan, McGraw HillEducation
[4] SteamTurbineTheoryandPractice,WilliamJ.Kearton,CBSPublication

[5] Suryanarayana,N.V.,andArici,O,DesignandSimulationofThermalSystems,McGrawHill.2001

CourseOutcomes

CO1: Skilltoidentifysuitablethermalplantforpowergenerationbasedontechno-economicconsiderations.

CO2:Abilityto do siteselection for apower plant.

CO3:Abilitytoanalysetheperformanceof thermalpower plants.

CO4:Skilltosuggest methodsforimprovingthe performanceofpowerplants.

CO5:Skilltoundertakeresearchstudies inconventionalandnon-conventionalpowerplants

		L	T	P	C
25TF657	**RenewableEnergy**	**3**	**0**	**0**	**3**

Module-1

Renewableenergysourcesin India-potentialsites,availability.

SolarEnergy:measurementandcollection,flatplatecollectors,concentrating collectors,solarponds, photovoltaic conversion, Thermalenergy storage,Potential andscope of solar cooling,Typesof solarcoolingsystems.

Ocean Energy: Principles of OTEC (Ocean Thermal Energy Conversion) - wave energy, tidal energy, energyconversion systems.

Module-2

Wind Energy: Principle, potential and status; Wind characteristics; Measurement of wind speed,Wind direction; National Wind Atlas; Theory of wind turbine blades; types of wind turbines andtheircharacteristics.

Bio-fuels: Sources and potential, properties and characterization; Biogas generation through aerobicand anaerobic digestion, bio-diesel and ethanol production and utilization. Thermo-chemical meth-ods of biofuel utilization: Combustion and gasification; utilization of producer gas for thermal andelectricitygeneration.

Module-3

Geo-thermalEnergy-nature,typesandutilization.

Recent trends in renewable energy- Flow Induced Vibration as a source of energy, Hydrogen energy.

Applications:Applications ofrenewable energysources-typical examples.Energyaudit.

TEXTBOOKS/REFERENCES

[1] Boyle&Godfrey,RenewableEnergy:Powerforasustainablefuture,ThirdEdition,OxfordUniversity Press, New York,2012.

[2] JohnTwidell&TonyWeir,RenewableEnergyResources,3rdEdition,TaylorandFrancis,2015

[3] AldoVRosa,FundamentalsofRenewableEnergyProcesses,2ndEdition,ElsevierInc,USA,2009.

[4] Craddock,D.,RenewableEnergyMadeEasy:FreeEnergyfrom Solar,Wind,Hydropowerandotheralternativeenergysources, AtlanticPublishingGroupInc., 2008.

[5] Wengenmayr,R.,Buhrke,T.,RenewableEnergy:SustainableEnergyConceptsforthefuture,Wiley-VCHVerlagGmbH &Co, Germany, 2008.

Courseoutcome

CO1:Explainthetechnicalfunctioningandprinciplesofvarioustechniquesfortheutilisationandconversionof renewableenergy

CO2:Mathematicallyillustrateandmodelrenewableenergyprocessesandperformcalculationsfordifferentte chnical solutions

CO3:

Identifydifferentchallengesinimplementationofdifferentrenewableenergysystems.CO4:Identifyth

escopeoffurther researchineachrenewable energytechnology.

25TF658	**Turbomachines**	**L**	**T**	**P**	**C**
		3	**0**	**0**	**3**

Module-1

Hydraulic machines: Impact of jets on vanes: flat, curved, stationary and moving vanes - radial flowover vanes. Impulse and reaction turbines: Design concepts- performance characteristics-workdoneandefficiencies.Centrifugalpumps:Workingprinciple–Performancecharacteristics–Energytransferand Efficiencies-NPSHCavitation – Trouble shooting.

Module-2

Thermal turbomachines: Fundamental equation of energy transfer - specific work- representation ofspecific work in T-S and H-S diagrams – performance - losses and efficiencies - flow coefficient - loading coefficient - degree of reaction - shape number - specific speed - polytropic efficiency - Two-dimensional cascade theory- Cascade nomenclature: lift and drag - losses and efficiency - compressorandturbinecascadeperformance-correlationsforturbineandcompressorperformance,Hawthorne's correlation-Soderberg's correlation

Module-3

Axialflowmachines:turbines,compressors,andfans-two-dimensionaltheory-Velocitydiagram -stagelossesandefficiency-designandoff-designcharacteristics,Centrifugalcompressors–theoreticalanalysis–impeller,diffuserandcasing- optimumdesignof compressor-inletpre-whirl -slipfactor-pressureratio-chokinginacompressorstage-surge,andstall.Radialflowturbines:typesof inlet flow –efficiency-off-design characteristics-loss coefficients.

ExperimentsandCFD:Experimentalmethodstomeasureflowandthermalfieldsinturbomachines
– ApplicationofCFDin analysis anddesignofturbomachinery.

TEXTBOOKS/REFERENCES

[1] YahyaS.M.,Turbines,CompressorsandFans,TataMcGrawHill,NewDelhi,4thEdition,2011.

[2] S.L.DixonandC.A.Hall,FluidMechanics,ThermodynamicsofTurbomachinery,PergamonPress,
7th Ed., 2014.

[3] Uzol.O and Katz.J, Flow measurement Techniques in Turbomachinery, Springer Handbook
ofExperimentalFluid Mechanics, 2007, pp. 919-957.

[4] PNModi.,S.M.Seth.,Hydraulics
andFluidMechanicsincludingHydraulicMachines,StandardBook House, 21st Ed, 2017.

[5] JournalsinTurbomachinery:ASMEJournalofTurbomachinery,ASMEJournalofEngineeringforG
asTurbinesandPower,AIAAJournalofPropulsion andPower.

CourseOutcomes

CO1: Capabilityto analysetheperformanceof turbomachines

CO2: Abilityto select turbomachines fordifferentapplications

CO3: Predictperformanceof turbomachineusingmodelanalysis

CO4: Conductresearchstudies onturbo machinestoimprovetheirperformance

■■

25AVP501   **MASTERY OVER MIND 1-0-2-2**

PG SYLLABUS
COURSE OBECTIVES
Master Over the Mind (MAOM) is an Amrita initiative to implement schemes and organize university-wide
programs to enhance health and wellbeing of all faculty, staff, and students (UN SDG -3). This program as part of
our efforts for sustainable stress reduction introduces immediate and long-term benefits and equips every attendee to
manage stressful emotions and anxiety facilitating inner peace and harmony. With a meditation technique offered by
Amrita Chancellor and world-renowned humanitarian and spiritual leader, Sri Mata Amritanandamayi Devi
(Amma), this course has been planned to be offered to all students of all campuses of AMRITA, starting off with all
first years, wherein one hour per week is completely dedicated for guided practical meditation session and one hour
on the theory aspects of MAOM. The theory section comprises lecture hours within a structured syllabus and will
include invited guest lecture series from eminent personalities from diverse fields of excellence. This course will
enhance the understanding of experiential learning based on university's mission: "Education for Life along with
Education for Living" and is aimed to allow learners to realize and rediscover the infinite potential of one's true
Being and the fulfilment of life's goals.
COURSE OUTCOME

After successful completion of the course, students will be able to:	
S.No.	**Course Outcomes**
1.	Understand the scientific benefits of meditation. (CO1)
2.	Explain the science behind meditation and its effects on physical and mental well-being

	(CO2).
3.	Understand the meditation techniques to cultivate emotional intelligence and improve relationships (CO3).
4.	Learn and practice MAOM meditation in daily life (CO4).
5.	To apply the effect of meditation to compassion-driven action (CO5)

Syllabus:
Scientific benefits of Meditation (CO1)
Scientific benefits of meditation, exploring its effects on physical and mental wellbeing.
Learn about the different types of meditation practices, the essential elements of meditation, and the empirical evidence supporting its benefits.
Video resource-Swami Atmanandamrita Puri

Science Behind Meditation (CO2)
A: A preliminary understanding of the Science of meditation. What can modern science tell us about this tradition-based method?
B: How meditation helps humanity according to what we know from scientific research
Reading 1: Does Meditation Aid Brain and Mental Health (Dr Shyam Diwakar)
Reading 2: 'Science and Spirituality.' Chapter 85 in Amritam Gamaya (2022). Mata Amritanandamayi Mission Trust.

Role of Meditation in Emotional intelligence (CO3)
Learn how meditation practices can enhance self-awareness, self-regulation, motivation, empathy, and social skills, leading to improved relationships and decision-making. Improve communication, emotional intelligence, and interpersonal skills.Logical and analytical reasoning

Practicing MA OM Meditation in Daily Life (CO4)
Guided Meditation Sessions following scripts provided (Level One to Level Five)
Reading 1: MA OM and White Flower Meditation: A Brief Note (Swami Atmananda Puri)
Reading 2: 'Live in the Present Moment.' Chapter 71 in Amritam Gamaya (2022). Mata Amritanandamayi Mission Trust.

Meditation and Compassion-driven Action (CO5)
Understand how meditation can help to motivate compassion-driven action.
Reading 1: Schindler, S., & Friese, M. (2022). The relation of mindfulness and prosocial behavior:What do we (not) know? Current Opinion in Psychology, 44, 151-156.
Reading 2: 'Sympathy and Compassion.' Chapter 100 in Amritam Gamaya (2022). Mata Amritanandamyi Mission Trust.

Textbooks / References:
1. Mata Amritanandamayi Devi, "Cultivating Strength and vitality," published by Mata Amritanandamayi Math, Dec 2019
2. Swami Amritaswarupananda Puri," The Color of Rainbow "published by MAM, Amritapuri. 3. Craig Groeschel, "Winning the War in Your Mind: Change Your Thinking, Change Your Life" Zondervan Publishers, February 2019
4. R Nagarathna et al, "New Perspectives in Stress Management "Swami Vivekananda Yoga Prakashana publications, Jan 1986
5. Swami Amritaswarupananda Puri "Awaken Children Vol 1, 5 and 7 - Dialogues with Amma on Meditation", August 2019
6. Swami Amritaswarupananda Puri "From Amma's Heart - Amma's answer to questions raised during world tours" March 2018
7. Secret of Inner Peace- Swami Ramakrishnananda Puri, Amrita Books, Jan 2018.
8. Mata Amritanandamayi Devi "Compassion: The only way to Peace:Paris Speech", MA Center, April 2016.
9. Mata Amritanandamayi Devi "Understanding and collaboration between Religions", MA Center, April 2016.
10. Mata Amritanandamayi Devi "Awakening of Universal Motherhood: Geneva Speech" M A center, April 2016.

GLIMPSES OF INDIAN CULTURE	
P/F	
22ADM501: GLIMPSES OF INDIAN CULTURE	
A. Prerequisite: nil	
B. Nature of Course: Theory	
C. Course Objectives:	

- The course "Glimpses of Indian Culture" aims to provide students with a comprehensive understanding of various aspects of Indian culture, with a focus on its spiritual, philosophical, and religious dimensions.
- Through an exploration of the chapters from the provided book, students will gain insights into the foundational principles, practices, and symbols that shape the diverse cultural landscape of India
- Aligned with the Indian Knowledge Systems (IKS) framework outlined in the National Education Policy, this course serves as an introduction to the vast reservoir of wisdom and knowledge rooted in Indian heritage.
- By engaging with the chapters in the book, students will develop a holistic appreciation for the rich tapestry of Indian culture, spanning from its philosophical underpinnings to its artistic expressions, rituals, and societal values.
- This course aims to cultivate cultural sensitivity, critical thinking, and a deeper understanding of the diverse spiritual and cultural traditions that have shaped India's identity over millennia.

D. Course Outcomes: After successful completion of the course, Students will be able to:

CO	Course Outcomes	Knowledge level [Bloom's Taxonomy]
CO01	**Recall key concepts and terms associated with Sanatana Dharma, scriptures, and core cultural elements of India.** Statement: Demonstrate the ability to remember essential terms, concepts, and principles discussed in the chapters on Sanatana Dharma, scriptures, and cultural aspects.	Remembering
CO02	**Explain the concepts of Īśvara, Guru Tattva, Avatara Tattva, and the Theory of Karma as foundational elements of Indian cultural philosophy.** Statement: Understand the profound meanings of Īśvara, Guru, Avatara, and Karma, elucidating their importance in shaping Indian cultural thought.	Understanding
CO03	**Apply the knowledge of Purusharthas, Sanyasa, and Yajna to analyze real-life ethical and spiritual scenarios.** Statement: Utilize insights from Purusharthas, Sanyasa, and Yajna to navigate ethical dilemmas and make informed decisions.	Applying
CO04	**Analyze the symbolism in cultural practices, Nataraja iconography, and temple architecture.** Statement: Deconstruct the layers of symbolism in various cultural aspects, including Nataraja representation and temple architecture, unraveling their deep meanings.	Analyzing
CO05	**Evaluate the significance of temples as cradles of culture and explore alternative systems in India's cultural landscape.**	Evaluating

CO06	**Develop projects or presentations that highlight the essence of Sanatana Dharma, sadhana, and the cultural significance of symbols.** Statement: Create expressive projects that capture the essence of Sanatana Dharma, convey the practices of sadhana, and portray the cultural meanings of symbols.	Creating

(continued from above)

| | Statement: Assess the role of temples in preserving cultural heritage and critically examine the diversity of cultural and spiritual systems in India. | |

POs Programme Outcomes	COs
PO1: Engineering Knowledge **PO2: Problem Analysis** **PO3: Design/Development of Solutions** **PO4: Conduct Investigations of complex problems** **PO5: Modern tools usage** **PO6: Engineer and Society** **PO7: Environment and Sustainability** **PO8: Ethics** **PO9: Individual & Teamwork** **PO10: Communication** **PO11: Project management & Finance** **PO12: Lifelong learning** **B.Tech. EEE Programme Specific Outcome (PSO)** **PSO1:** Awareness of Future Technology: Develop solutions for future systems using smart technologies. **PSO2:** Research and Innovation: Identify engineering challenges, approach using cutting edge research tools and execute innovative solutions.	• CO 1: Recall key concepts and terms associated with Sanatana Dharma, scriptures, and core cultural elements of India. • CO 2: Explain the concepts of Īśvara, Guru Tattva, Avatara Tattva, and the Theory of Karma as foundational elements of Indian cultural philosophy • CO 3: Apply the knowledge of Purusharthas, Sanyasa, and Yajna to analyze real-life ethical and spiritual scenarios. • CO 4: Analyze the symbolism in cultural practices, Nataraja iconography, and temple architecture. • CO 5: Evaluate the significance of temples as cradles of culture and explore alternative systems in India's cultural landscape. • CO 6: Develop projects or presentations that highlight the essence of Sanatana Dharma, sadhana, and the cultural significance of symbols.

E. CO-PO Mapping: [affinity[#]: 3 – high; 2- moderate; 1- slightly]

COs	Program Outcomes [POs]												Program Specific Outcomes [PSOs]*	
	PO1	PO2	PO3	PO4	PO5	PO6	PO7	PO8	PO9	PO10	PO11	PO12	PSO1	PSO2
CO01	-	-	-	-	-	-	-	2	-	-	-	3	-	-
CO02	-	-	-	-	-	1	-	2	-	-	-	3	-	-
CO03	-	-	-		-	3	3	3	2	-	-	2	-	-
CO04	-	-	-	-	-	3	-	-	-	-	-	3	-	-
CO05	-	-	-	-	-	2	3	-	-	-	-	2	-	-
CO06	-	-	-	-	-	2	2	2	2	-	-	3	-	-
Total														
Average														

F. SYLLABUSGLIMPSES OF INDIAN CULTURE   [P/F]

Course Syllabus

Chapter 1	-	*What is Sanatana Dharma*
Chapter 2	-	*The Heritage of Scriptures*
Chapter 3	-	*The idea of Īśvara*
Chapter 4	-	*Guru Tattva and Avatara Tattva*
Chapter 5	-	*Theory of Karma*
Chapter 6	-	*Purusharthas*
Chapter 7	-	*Sanyasa*
Chapter 8	-	*Yajna*
Chapter 9	-	*Symbolism*
Chapter 10	-	*Understanding Nataraja*
Chapter 11	-	*Temples: The Cradle of Culture*
Chapter 12	-	*Other Heterodox Systems in India*
Chapter 13	-	*Sadhana*

GLIMPSES OF INDIAN CULTURE

Reference Books:

The Eternal Truth by Mata Amritanandamayi Devi
Temples: Centers for Spiritual Practice by Mata Amritanandamayi Devi
All About Hinduism by Swami Sivananda
Art of God Symbolism by Swami Chinmayananda
Temples in India by Swami Sivananda

G. Evaluation Pattern: 60:40

Component	Weightage	Remarks
Internal	60	-
External	40	-
TOTAL	100	

23HU601	Career Competency I	L-T-P-C: 0-0-3-P/F

Prerequisite:
An open mind and the urge for self-development, basic English language skills and knowledge of high school level arithmetic.

Course Objectives:
- Help students transit from campus to corporate and enhance their soft skills
- Enable students to understand the importance of goal setting and time management skills
- Support them in developing their problem solving and reasoning skills
- Inspire students to enhance their diction, grammar and verbal reasoning skills

Course Outcomes:
CO1:Soft Skills - To develop positive mindset, communicate professionally, manage time effectively and set personal goals and achieve them.
CO2:Soft Skills - To make formal and informal presentations with self-confidence.
CO3:Aptitude - To analyze, understand and employ the most suitable methods to solve questions on arithmetic and algebra.
CO4:Aptitude - To analyze, understand and apply suitable techniques to solve questions on logical reasoning and data analysis.
CO5:Verbal - To infer the meaning of words and use them in the right context. To have a better understanding of

the nuances of English grammar and become capable of applying them effectively.

CO6:Verbal - To identify the relationship between words using reasoning skills. To understand and analyze arguments and use inductive/deductive reasoning to arrive at conclusions and communicate ideas/perspectives convincingly.

CO-PO Mapping

PO/CO	PO1	PO2	PO3
CO1	2	1	-
CO2	2	1	-
CO3	2	1	-
CO4	2	1	-
CO5	1	2	-
CO6	2	2	-

Syllabus:

Soft Skills

Introduction to 'campus to corporate transition':

Communication and listening skills: communication process, barriers to communication, verbal and non-verbal communications, elements of effective communication, listening skills, empathetic listening, role of perception in communication.

Assertiveness skills: the concept, assertiveness and self-esteem, advantages of being assertive, assertiveness and organizational effectiveness.

Self-perception and self-confidence: locus of control (internal v/s external), person perception, social perception, attribution theories-self presentation and impression management, the concept of self and self-confidence, how to develop self-confidence.

Goal setting: the concept, personal values and personal goals, goal setting theory, six areas of goal setting, process of goal setting: SMART goals, how to set personal goals

Time management: the value of time, setting goals/ planning and prioritizing, check the time killing habits, procrastination, tools for time management, rules for time management, strategies for effective time management

Presentation skills: the process of presentation, adult learning principles, preparation and planning, practice, delivery, effective use of voice and body language, effective use of audio visual aids, dos and don'ts of effective presentation

Public speaking-an art, language fluency, the domain expertise (Business GK, Current affairs), self-confidence, the audience, learning principles, body language, energy level and conviction, student presentations in teams of five with debriefing

Verbal

Vocabulary: Familiarize students with the etymology of words, help them realize the relevance of word analysis and enable them to answer synonym and antonym questions. Create an awareness about the frequently misspelt words, commonly confused words and wrong form of words in English.

Grammar: Train students to understand the nuances of English Grammar and thereby enable them to spot grammatical errors and punctuation errors in sentences.

Reasoning: Stress the importance of understanding the relationship between words through analogy questions and learn logical reasoning through syllogism questions. Emphasize the importance of avoiding the gap (assumption) in arguments/ statements/ communication.

Oral Communication Skills: Aid students in using the gift of the gab to improve their debating skills.

Writing Skills: Introduce formal written communication and keep the students informed about the etiquettes of email writing. Make students practise writing emails especially composing job application emails.

Aptitude

Numbers: Types, Power Cycles, Divisibility, Prime, Factors & Multiples, HCF & LCM, Surds, Indices, Square roots, Cube Roots and Simplification.

Percentage: Basics, Profit, Loss & Discount, and Simple & Compound Interest.

Ratio, Proportion & Variation: Basics, Alligations, Mixtures, and Partnership.

Averages: Basics, and Weighted Average.

Time and Work: Basics, Pipes & Cistern, and Work Equivalence.

Time, Speed and Distance: Basics, Average Speed, Relative Speed, Boats & Streams, Races and Circular tracks.

Statistics: Mean, Median, Mode, Range, Variance, Quartile Deviation and Standard Deviation.

Data Interpretation: Tables, Bar Diagrams, Line Graphs, Pie Charts, Caselets, Mixed Varieties, and other forms of data representation.

Equations: Basics, Linear, Quadratic, Equations of Higher Degree and Problems on ages.

Logarithms, Inequalities and Modulus: Basics

References

Soft Skills:

Communication and listening skills:
- Andrew J DuRbin , "Applied Psychology: Individual and organizational effectiveness", Pearson- Merril Prentice Hall, 2004
- Michael G Aamodt, "An Applied Approach, 6th edition", Wadsworth Cengage Learning, 2010

Assertiveness skills:
- Robert Bolton, Dorothy Grover Bolton, "People Style at Work..and Beyond: Making Bad Relationships Good and Good", Ridge Associates Inc., 2009
- John Hayes "Interpersonal skills at work", Routledge, 2003
- Nord, W. R., Brief, A. P., Atieh, J. M., & Doherty, E. M., "Meanings of occupational work: A collection of essays (pp. 21- 64)", Lexington, MA: Lexington Books, 1990

Self-perception and self-confidence:
- Mark J Martinko, "Attribution theory: an organizational perspective", St. Lucie, 1995
- Miles Hewstone, "Attribution Theory: Social and Functional Extensions", Blackwell, 1983

Time management:
- Stephen Covey, "The habits of highly effective people", Free press Revised edition, 2004
- Kenneth H Blanchard , "The 25 Best Time Management Tools & Techniques: How to Get More Done Without Driving Yourself Crazy" , Peak Performance Press, 1st edition 2005
- Kenneth H. Blanchard and Spencer Johnson, "The One Minute Manager", William Morrow, 1984

Verbal:
- Erica Meltzer, "The Ultimate Guide to SAT Grammar"
- Green, Sharon, and Ira K. Wolf, "Barron's New GRE", Barron's Educational Series, 2011
- Jeff Kolby, Scott Thornburg & Kathleen Pierce, "Nova's GRE Prep Course"
- Kaplan, "Kaplan New GRE Premier", 2011-2012
- Kaplan's GRE Comprehensive Programme
- Lewis Norman, "Word Power Made Easy", Goyal Publishers, Reprint edition, 1 June 2011
- Manhattan Prep, "GRE Verbal Strategies Effective Strategies Practice from 99th Percentile Instructors"
- Pearson- "A Complete Manual for CAT", 2013
- R.S. Aggarwal, "A Modern Approach to Verbal Reasoning"
- S. Upendran, "Know Your English", Universities Press (India) Limited, 2015
- Sharon Weiner Green, Ira K. Wolf, "Barron's New GRE, 19th edition (Barron's GRE)", 2019
- Wren & Martin, "English Grammar & Composition"
- www.bbc.co.uk/learningenglish
- www.cambridgeenglish.org
- www.englishforeveryone.org
- www.merriam-webster.com

Aptitude:
- Arun Sharma, "How to Prepare for Quantitative Aptitude for the CAT Common Admission Test", Tata Mc Graw Hills, 5th Edition , 2012
- Arun Sharma, "How to Prepare for Logical Reasoning for the CAT Common Admission Test", Tata Mc Graw Hills, 2nd Edition, 2014
- Arun Sharma, "How to Prepare for Data Interpretation for the CAT Common Admission Test", Tata Mc Graw Hills, 3nd Edition, 2015
- R.S. Aggarwal, "Quantitative Aptitude For Competitive Examinations", S. Chand Publishing, 2015
- R.S. Aggarwal, "A Modern Approach To Verbal & Non-Verbal Reasoning", S. Chand Publishing, Revised - 2015
- Sarvesh Verma, "Quantitative Aptitude-Quantum CAT", Arihant Publications, 2016
- www.mbatious.com
- www.campusgate.co.in
- www.careerbless.com

Evaluation Pattern

Assessment	Internal	External

Continuous Assessment (CA)* – Soft Skills	30	-
Continuous Assessment (CA)* – Aptitude	10	25
Continuous Assessment (CA)* – Verbal	10	25
Total	50	50

Pass / Fail

 *CA - Can be **presentations, speaking activities and tests.**

23HU611	Career Competency II	L-T-P-C:0-0-3-1

Pre-requisite: Willingness to learn, team spirit, basic English language and communication skills and knowledge of high school level arithmetic.

Course Objectives:
- Help students to understand the importance of interpersonal skills and team work
- Prepare the students for effective group discussions and interviews participation.
- Help students to sharpen their problem solving and reasoning skills
- Empower students to communicate effectively by using the correct diction, grammar and verbal reasoning skills

Course Outcomes:

CO1:Soft Skills - To demonstrate good interpersonal skills, solve problems and effectively participate in group discussions.

CO2:Soft Skills - To write technical resume and perform effectively in interviews.

CO3:Aptitude - To identify, investigate and arrive at appropriate strategies to solve questions on arithmetic by managing time effectively.

CO4:Aptitude - To investigate, understand and use appropriate techniques to solve questions on logical reasoning and data analysis by managing time effectively.

C05:Verbal - To be able to use diction that is more refined and appropriate and to be competent in knowledge of grammar to correct/improve sentences

C06:Verbal - To be able to examine, interpret and investigate passages and to be able to generate ideas, structure them logically and express them in a style that is comprehensible to the audience/recipient.

CO-PO Mapping

PO/CO	PO1	PO2	PO3
CO1	2	1	-
CO2	2	1	-
CO3	2	1	-
CO4	2	1	-
CO5	1	2	-
CO6	2	2	-

Syllabus

Soft Skills

Interpersonal skill: ability to manage conflict, flexibility, empathetic listening, assertiveness, stress management, problem solving, understanding one's own interpersonal needs, role of effective team work in organizations

Group problem solving: the process, the challenges, the skills and knowledge required for the same.

Conflict management: the concept, its impact and importance in personal and professional lives, (activity to identify personal style of conflict management, developing insights that helps in future conflict management situations.)

Team building and working effectively in teams: the concept of groups (teams), different stages of group formation, process of team building, group dynamics, characteristics of effective team, role of leadership in team effectiveness. (Exercise to demonstrate the process of emergence of leadership in a group, debrief and reflection), group discussions.

Interview skills: what is the purpose of a job interview, types of job interviews, how to prepare for an interview, dos and don'ts of interview, One on one mock interview sessions with each student

Verbal

Vocabulary: Help students understand the usage of words in different contexts. Stress the importance of using refined language through idioms and phrasal verbs.

Grammar: Enable students to identify poorly constructed sentences or incorrect sentences and improvise or correct them.

Reasoning: Facilitate the student to tap her/his reasoning skills through critical reasoning questions and logical ordering of sentences.

Reading Comprehension: Enlighten students on the different strategies involved in tackling reading comprehension questions.

Public Speaking Skills: Empower students to overcome glossophobia and speak effectively and confidently before an audience.

Writing Skills: Practice closet tests that assess basic knowledge and skills in usage and mechanics of writing such as punctuation, basic grammar and usage, sentence structure and rhetorical skills such as writing strategy, organization, and style.

Aptitude

Sequence and Series: Basics, AP, GP, HP, and Special Series.

Geometry: 2D, 3D, Coordinate Geometry, and Heights & Distance.

Permutations & Combinations: Basics, Fundamental Counting Principle, Circular Arrangements, and Derangements.

Probability: Basics, Addition & Multiplication Theorems, Conditional Probability and Bayes' Theorem.

Logical Reasoning I: Arrangements, Sequencing, Scheduling, Venn Diagram, Network Diagrams, Binary Logic, and Logical Connectives, Clocks, Calendars, Cubes, Non-Verbal reasoning and Symbol based reasoning.

Logical Reasoning II: Blood Relations, Direction Test, Syllogisms, Series, Odd man out, Coding & Decoding, Cryptarithmetic Problems and Input - Output Reasoning.

Data Sufficiency: Introduction, 5 Options Data Sufficiency and 4 Options Data Sufficiency.

Campus recruitment papers: Discussion of previous year question papers of all major recruiters of Amrita Vishwa Vidyapeetham.

Miscellaneous: Interview Puzzles, Calculation Techniques and Time Management Strategies.

References

Soft Skills

Team Building

- Thomas L.Quick, "Successful team building", AMACOM Div American Mgmt Assn, 1992
- **Brian Cole Miller, "Quick Team-Building Activities for Busy Managers: 50 Exercises That Get Results in Just 15 Minutes", AMACOM; 1 edition, 2003.**
- **Patrick Lencioni, "The Five Dysfunctions of a Team: A Leadership Fable", Jossey-Bass, 1st Edition, 2002**

Verbal

- "GMAT Official Guide" by the Graduate Management Admission Council, 2019
- Arun Sharma, "How to Prepare for Verbal Ability And Reading Comprehension For CAT"
- Joern Meissner, "Turbocharge Your GMAT Sentence Correction Study Guide", 2012
- Kaplan, "Kaplan GMAT 2012 & 13"
- Kaplan, "New GMAT Premier", Kaplan Publishing, U.K., 2013
- Manhattan Prep, "Critical Reasoning 6th Edition GMAT"
- Manhattan Prep, "Sentence Correction 6th Edition GMAT"
- Mike Barrett "SAT Prep Black Book The Most Effective SAT Strategies Ever Published"
- Mike Bryon, "Verbal Reasoning Test Workbook Unbeatable Practice for Verbal Ability, English Usage and Interpretation and Judgement Tests"
- www.bristol.ac.uk/arts/skills/grammar/grammar_tutorial/page_55.htm
- www.campusgate.co.in

Aptitude

- Arun Sharma, "How to Prepare for Quantitative Aptitude for the CAT Common Admission Test", Tata Mc Graw Hills, 5th Edition, 2012
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- Sarvesh Verma, "Quantitative Aptitude-Quantum CAT" , Arihant Publications , 2016
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