Courses of Study

PhD Mechanical Engineering

Department of Mechanical Engineering
Islamic University of Science and Technology, Kashmir

Course Outline for Core Courses

S.No.	Course Code	Course Title	L	T	P	S	Hours Per Week	Credits
1	SET801F	Research and Publication Ethics	2	0	0	0	0	2
2	SET802F	Research Methodology for Engineering and Technology	4	0	0	0	0	4

Course Outline Departmental Electives

S.No.	Course Code	Course Title	L	T	P	S	Hours Per Week	Credits
1	MEC701E	Fluid Mechanics and Heat Transfer Characteristics of NanoFluids	3	0	0	0	3	4
2	MEC702E	Hydrogen Energy Structure	3	0	0	0	3	4
3	MEC703E	Lubricant Selection and Applications	3	0	0	0	3	4
4	MEC704E	Manufacturing of Non-Metallic Products	3	0	0	0	3	4
5	MEC705E	Sustainable Manufacturing	3	0	0	0	3	4
6	MEC706E	Friction Wear and Lubrication	4	0	0	0	4	4
7	MEC707E	Tribo-Materials	3	0	0	0	3	4
8	MEC708E	Advanced Fluid Dynamics	3	0	0	0	3	4
9	MEC709E	Advanced Heat Transfer	3	0	0	0	3	4
10	MEC802C	Finite Element Analysis	3	1	0	0	4	4
11	MEC803E	Robot Mechanics and Control	3	0	2	0	5	4
12	MEC804E	Advanced Manufacturing Systems	3	0	0	0	3	3
13	MEC805E	Computational Heat Transfer and Fluid Flow	3	0	2	0	3	4

Detailed Syllabus for Core Courses

S.No.	Course Code	Course Title	L	T	P	S	Hours Per Week	Credits
1	SET801F	Research and Publication Ethics	2	0	0	0	0	2
2	SET802F	Research Methodology for Engineering and Technology	4	0	0	0	0	4

Research and Publication Ethics
SET801F

- RPE 01: PHILOSOPHY AND ETHICS (3 hrs.)

1. Introduction to philosophy: definition, nature and scope, concept, branches
2. Ethics: definition, moral philosophy, nature of moral judgements and reactions

- RPE 02: SCIENTIFICCONDUCT (5hrs.)

1. Ethics with respect to science and research
2. Intellectual honesty and research integrity
3. Scientific misconducts: Falsification, Fabrication, and Plagiarism (FFP)
4. Redundant publications: duplicate and overlapping publications, salami slicing
5. Selective reporting and misrepresentation of data

- RPE 03: PUBLICATION ETHICS (7 hrs.)

1. Publication ethics: definition, introduction and importance
2. Best practices / standards setting initiatives and guidelines: COPE, WAME, etc.
3. Conflicts of interest
4. Publication misconduct: definition, concept, problems that lead to unethical behavior and vice versa, types
5. Violation of publication ethics, authorship and contributorship
6. Identification of publication misconduct, complaints and appeals
7. Predatory publishers and journals

PRACTICE

- RPE 04: OPEN ACCESS PUBLISHING(4 hrs.)

1. Open access publications and initiatives
2. SHERPA/RoMEO online resource to check publisher copyright & self-archiving policies
3. Software tool to identify predatory publications developed by SPPU
4. Journal finder / journal suggestion tools viz. JANE, Elsevier Journal Finder, Springer Journal Suggester, etc.

- RPE 05: PUBLICATION MISCONDUCT (4hrs.)

A. Group Discussions (2 hrs.)

1. Subject specific ethical issues, FFP, authorship
2. Conflicts of interest
3. Complaints and appeals: examples and fraud from India and abroad

B. Software tools (2 hrs.)

Use of plagiarism software like Turnitin, Urkund and other open source software tools

- RPE 06: DATABASES AND RESEARCH METRICS (7hrs.)

A. Databases (4 hrs.)
   1. Indexing databases
   2. Citation databases: Web of Science, Scopus, etc.

B. Research Metrics (3 hrs.)
   1. Impact Factor of journal as per Journal Citation Report, SNIP, SJR, IPP, Cite Score
   2. Metrics: h-index, g index, i10 index, altmetrics

References

Bird, A. (2006). Philosophy ofScience. Routledge.

MacIntyre, Alasdair (1967) A Short Histopy ofEthics. London.

P. Chaddah, (2018) Ethics in Competitive Research: Do not get scooped; do not get plagiarized, ISBN:9789387480865

National Academy of Sciences, National Academy of Engineering and Institute of Medicine. (2009). On Being a Scientist: A Guide to Responsible Conduct in Research: Third Edition. National Academies Press. Resnik, D. B. (2011). What is ethics in research & why is it important. National Institute ofEnvironmental Health Sciences, 1—10. Retrieved from https://www.niehs.nih.gov/research/resources/bioethics/whatis/index.cfin

Beall, J. (2012). Predatory publishers are corrupting open access. Nature, 489(7415), 179—179. https://doi.org/10.1038/489179a

Indian National Science Academy (INSA), Ethics in Science Education, Research and Governance(2019), ISBN:978-81-939482-1-7. http://www.insaindia.res.in/pdffEthics Book.pdf

Research Methodology for Engineering & Technology

SET802F

Unit-I (12 hours) Science and Scientific research

Knowledge and the epistemology of knowledge, deductive and inductive inference. A brief history of scientific ideas, important thinkers, scientists and scientific advancements. Principles of effective research, aspects of research - self-development and the creative process, the problem-solver and the problem-creator; Finding and solving research problems, Literature survey, developing a research plan, research proposals.

Unit-II (12 hours) Computational thinking and statistical analysis:

Measures of central tendency, Data and its nature, data representation, curve plotting using MS-Excel and Origin. Hypothesis testing concept of p-value. Student's t-test and F-test. ANOVA(one way and two way), transformation of data. Tests of significance, non-parametric tests, simple, partial and multiple correlations. Basic principles of Statistical Computation using various softwares; design of experiments and analysis of results using various softwares (MATLAB, ORIGIN, SPSS, Design Expert, etc)

Unit-III (10 hours): Scientific Writing:

The research report, Steps in writing a report, Layout of the research report, Writing references and bibliography. Presentations: Importance of effective presentation, Planning a good presentation. Scientific Papers: How to write good papers, models of the paper writing process, identifying ideas and telling the story, The benefits of targeting good journals, Peer review, How to respond to reviewer comments, reviewing a paper. Identification of publication misconduct, complaints and appeals Predatory publishers and journals

Unit-IV (10 hours):

Technical and Scientific documentation using Latex: What is LATEX?, A short history of TEX, Main attractions of LATEX: Automatic Styling according to Journal requirements, Cross references, Writing Complex Maths. The LATEX document, Typical Input Files, Post-processed look, The Edit/Format/Preview Process, Embedding References in the Document, Bibliography management using BIBTEX, Presentations using Beamer, Introduction to Overleaf, Hands-on sessions on LATEX.

Unit-V (16 hours):

Modelling, Simulation and Data analysis using software tools: Introduction, Variable types, arrays and matrices, multidimensional arrays, subarrays, operations, functions, using functions with array inputs, Displaying output data. Two Dimensional Plotting, multiple plots, subplots, Logarithmic and Polar plots. Control Flow/Branching Statements: Logical data type, Relational operators, if – else, switch – case, Loops– While and For loops, nested loops. User defined functions. Additional Data and Plot Types: Complex Data, Complex numbers with relational operators, Complex functions, String functions, 3D line plots, 3D surface, mesh and contour plots, Introduction to Optimal Design using software tools.

Detailed Syllabus for Departmental Electives

S.No.	Course Code	Course Title	L	T	P	S	Hours Per Week	Credits
1	MEC701E	Fluid Mechanics and Heat Transfer Characteristics of NanoFluids	3	0	0	0	3	4
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3	MEC703E	Lubricant Selection and Applications	3	0	0	0	3	4
4	MEC704E	Manufacturing of Non-Metallic Products	3	0	0	0	3	4
5	MEC705E	Sustainable Manufacturing	3	0	0	0	3	4
6	MEC706E	Friction Wear and Lubrication	4	0	0	0	4	4
7	MEC707E	Tribo-Materials	3	0	0	0	3	4
8	MEC708E	Advanced Fluid Dynamics	3	0	0	0	3	4
9	MEC709E	Advanced Heat Transfer	3	0	0	0	3	4
10	MEC802C	Finite Element Analysis	3	1	0	0	4	4
11	MEC803E	Robot Mechanics and Control	3	0	2	0	5	4
12	MEC804E	Advanced Manufacturing Systems	3	0	0	0	3	3
13	MEC805E	Computational Heat Transfer and Fluid Flow	3	0	2	0	3	4

MEC701E **Fluid Mechanics and Heat Transfer Characteristics of NanoFluids** **3-0-0**

Course Objectives: This course will enable students to:

1. Learn the applications of nanotechnology in the area of fluids and thermal engineering.
2. Demonstrate the superior thermophysical properties of nanofluids.
3. learn the various experimental and numerical approaches for the determination of thermo-physical properties

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Course Outcomes: At the end of this course, a student will be able to:

1. Explain the various preparation techniques with enhanced stability
2. Explain the various experimental techniques for the determination of thermo-physical properties.
3. Predict the behavior of nanofluids using theoretical and empirical models and effect on various parameters
4. Illustrate the convective heat transfer
5. Articulate the various application of nanofluids

Module I

Introduction to nanofluids, types of nanofluids, preparation techniques, base fluids, dispersion and Sonification, stability of nanofluids, and methods to enhance the stability of nanofluids, Various volumetric concentrations.

Module II

Experimental Methods for the Characterization of Thermo physical Properties of Nanofluids principles of measurement and apparatus for Density, viscosity, thermal conductivity, and specific heat. Characterization techniques for morphology, rheological and optical properties.

Module III

Theoretical equations and empirical correlations to determine the density, viscosity, thermal conductivity of different nanofluids. Effect of volumetric concentration and temperature. Effect of Brownian motion on thermo-physical properties, Possible Mechanisms of thermal conductivity enhancement.

Module IV

Combined effects of thermo physical properties of nanofluids on the thermal diffusivity, the Prandtl number, the Reynolds number and the Nusselt number. Basic understanding of their effects on frictional loss and heat transfer. Convective heat transfer: Single-phase fluid equations, laminar flow, entry length and fully developed friction factor and heat transfer coefficient. Graetz number effect in the entry region. Correlations for friction factor and Nusselt number for nanofluids.

Module V

Application of nanofluids to various types of industrial heat exchangers. Application to building heating and cooling, Application of nanofluids in solar energy, Application to automobile radiators, introduction to electronic cooling in microchannels with nanofluids.

Text Books:

1. V. Bianco, O. Manca, S. Nardini and K. Vafai, Heat Transfer Enhancement with nanofluids CRC Press
2. C. Sobhan and G. Peterson, Microscale and Nanoscale Heat Transfer, First edition, CRC Press

Reference Books:

1. A. Bejan,Heat Transfer, 2nd Edition, John Wiley.
2. F. M. White, Fluid Mechanics, Sth Edition, McGraw-Hill
3. W. J. Minkowycz, E. M. Sparrow, J. P. Abraham, Nanoparticle heat transfer and fluid flow
4. S. K. Das, S. U. Choi, W. Yu and T. Pradeep, Nanofluids Science and Technology
5. P. Abgrall, N.T. Nguyen, Nanofluidics, 2009.

Online Resources:

1. Micro and Nanoscale Energy Transport by Dr. Arvind Pattamatta (IIT Madras) NPTEL Course (https://nptel.ac.in/courses/112106222).

MEC702E Hydrogen Energy Structure 3-0-0

Course Objectives: This course will enable students to:

1. Learn about the production of hydrogen.
2. Learn about storage pathways of hydrogen.
3. Learn about the use of hydrogen as an energy carrier through Fuel cells and ICEs.

Course Outcomes: At the end of this course, a student will be able to:

1. Explain the different methods of hydrogen production
2. Explain the working of the electrolyzers
3. Describe the storage of hydrogen through compression, liquefaction and absorption
4. Describe the construction and working of Fuel Cells
5. Explain the global and local hydrogen energy scenario

Module I

Properties of hydrogen, global status of supply and demand, methods of hydrogen production, steam reforming, partial oxidation, autothermal reforming, combined reforming, reforming using alternative energy sources, Hydrogen production from methane decomposition, from coal and biomass. Hydrogen separation and purification

Module II

Thermochemical hydrogen production, Components of electrolytic cell, configuration of electrolyzer stack, different electrolyzer technologies, photoelectrochemical hydrogen production, technical and economic comparison of different production methods and global status, cost analysis

Module III

Introduction to hydrogen storage, underground hydrogen storage, fundamentals of hydrogen compression and expansion, Mechanical and non-mechanical hydrogen compressors; compressed hydrogen tank types and design considerations, Hydrogen liquefaction, liquid state hydrogen storage tanks, fundamentals of hydrogen storage in adsorption based materials

Module IV

Fundamentals and thermodynamics of absorption based hydrogen storage, metal hydrides, types of metal hydrides, metal hydride based systems design, Novel materials for solid state hydrogen storage; economics of storage; Long distance hydrogen transport via pipelines, ships and in form of LOHC; hydrogen transport via road; hydrogen refuelling stations

Module V

Use of hydrogen in internal combustion engines, fuel cells, hydrogen sensing, Properties of hydrogen associated with hazards, classification of hydrogen hazards, compressed and liquid hydrogen related hazards, regulation, codes and standards, utilisation of hydrogen in various sectors, global status and future directions

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Text Books:

1. Gupta, R. B., Hydrogen Fuel: Production, Transport and Storage, CRC Press, Taylor & Francis Group, 2009.

2. Global Hydrogen Review 2021, IEA (2021), Paris, https://www.iea.org/reports/global-hydrogen-review-2021

Reference Books:

1. Michael Hirscher, Handbook of Hydrogen Storage, Wiley-VCH, 2010.

Online Resources:

1. Hydrogen Energy: Production, Storage, Transportation and Safety by Prof. Pratibha Sharma (IIT Bombay), NPTEL Course (https://onlinecourses.nptel.ac.in/noc22_ch66/preview).

MEC703E Lubricant Selection and Applications 3-0-0

Course Objectives: This course will enable students to:

1. Provide the knowledge lubricants and their types
2. Introduce the solid lubricants and their applications
3. Understand the viscosity aspects of lubricants

Course Outcomes: At the end of this course, a student will be able to:

1. Explain the types of lubricants and their classification based on viscosity index
2. Select the solid lubricants based on the applications
3. Explain the viscosity and effect of various parameters like temperature on lubricants

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Module I

Introduction: Introduction, liquid lubricants, mineral oils, classification, types of crude petroleum, classification by viscosity index, hydrocarbon types, physical properties, refining, synthetic Oils, Di-Esters. Polyol Esters ,Polyglycols, Phosphate Esters, Silicones, Silicate Esters and disiloxoxanes, Polyphenyl Ethers, C-Ethers, other organic liquids, Liquid glasses, liquefied oxides, liquid metals, greases, types of greases, soap base or thickner-lime, sodium and calcium etc, greases containing esters, silicones, consistency and grease selection, tribological implications, environmental issues.

Module II

Solid lubricants: Molybdenum disulphide and similar compounds, Graphite, Calcium fluoride and barium fluoride, graphite fluoride, polymers, metals as solid lubricants, other inorganic solid lubricants, self-lubricating composites, PTFE composites, Molybednum disulphide composites, graphite composites, calcium fluoride composites, physical and chemical properties of lubricants..

Module III

Viscosity of lubricants: Effect of temperature, pressure and shear rates on viscosity, measurement of viscosity, relative density, specific heat and thermal conductivity, acidity and alkalinity, oxidation stability. Flash point, foaming, pour point, demulsibility, extreme pressure additives .Lubrication between the piston rings and cylinder wall of a running engine, effect of speed, effect of viscosity and temperature, lubrication between a journal and bearing, effect of load, speed, viscosity and temperature, effect of temperature on lubricant films.

Pre-requisites: Fundamentals of Tribology

Text Books:

1. B. Bharat, Introduction to tribology, John Wiley & Sons, Inc, 2002
2. A.R. Lansdown, High temperature lubrication, Mechanical Engineering Publications Limited London, 1994 S

Reference Books:

1. F. Bowden and D. Tabor, The friction and lubrication of solids, Clarendon Press Oxford 1986.

Online Resources:

1. Friction and wear of materials: principles and case studies by Prof. Dr. B. V Manoj Kumar (IIT Roorkee), NPTEL Course (https://archive.nptel.ac.in/courses/113/108/113108083/).

MEC704E Manufacturing of Non-Metallic Products 3-0-0

Course Objectives: This course will enable students to gain knowledge about the characteristics, classifications, processing and application of Polymers, Rubber, Glass, ceramic and composite materials.

Course Outcomes: At the end of this course, a student will be able to:

1. Describe the types of polymers and its manufacturing techniques.
2. Explain the Processing and Usages of Rubber in various industries.
3. Describe the application, types of glass and ceramics and their manufacturing methods
4. Knowledge in types of composites and their manufacturing techniques

Module I

Polymers:- Classification - Thermoplastics and thermosetting plastics,Thermoforming processes-compression and transfer moulding - injection moulding - extrusion - blow moulding – calendaring-lamination and pultrusion.

Module II

Rubber - Applications. Stages in raw rubber and latex rubber technology - Processing of rubbers –Manufacturing techniques, tires, belts, hoses, foot wears, cellular products, cables. Manufacture of latex based product.s

Module III

Glass - characteristics - application - glass making - Glass forming machines - hollow wares, flat glasses, fibreglass, bulbs, bottles, heat absorbing glasses, amber glass and their manufacturing methods, general plant layouts for manufacture of different types of glasses.

Module IV

Ceramics - classification - traditional ceramics,structural ceramics ,fine ceramics, bio ceramics, ceramic superconductors. Ceramic processing techniques - hot pressing - hot isostatic pressing (HIP) - Sintering - injection moulding, slip casting, tape casting, gel casting, extrusion.

Module V

Composites - requirements of reinforcement and matrix - Manufacturing of composites - casting - solid state diffusion - cladding - HIP - liquid metal infiltration - liquid phase sintering preparation of moulding compounds and prepregs - hand layup method - autoclave method filament winding method - compression moulding - reaction injection moulding - knitting - braiding.

Pre-requisites: NA

Text Books:

1. Ghosh, Polymer Science and Technology – Plastics, Rubber, Blends, and Composites, TataMcGraw-Hill, 1989.
2. J. L. White, Rubber Processing Technology, Materials and Principles, Hanser Publishers, 1995.
3. E. B. Shand, Glass Engineering Handbook, McGraw-Hill, 2nd Edition, 1958.

4. W. D. Kingery & ETC, Introduction to Ceramics, 2nd edition, John Wiley & Sons, 2004.

Online Resources:

1. Manufacturing of Non-Metallic Products by Professor H. S. Shan (IIT Roorkee), NPTEL course (https://nptel.ac.in/courses/112107144/#).

MEC705E Sustainable Manufacturing 3-0-0

Course Objectives: This course will enable students to:

1. Create the awareness of sustainability practices in manufacturing.
2. Inculcate knowledge on performing life cycle analysis

Course Outcomes: At the end of this course, a student will be able to:

1. Explain the concept of sustainable development with their physical significance in manufacturing as well as in general life situations.
2. Know the impact of R3 and R6 cycles in enhancing the environmental standards and on other relevant sustainable parameters.
3. Explain the Interactions between energy and technology and their implications for environment and sustainable development.
4. Know the Eco friendly product design methods.
5. Visualise the set-up parameters for designing a recycling system and assessment of that using various analytical methods to know its robustness.

Module I

Concepts of sustainability and sustainable development: Need for sustainable development - Components of sustainability- Social, Economic, Environmental dimensions - Linkages between technology and sustainability - Sustainable Manufacturing –Scope, Need and Benefits.

Module II

Tools and Techniques of Sustainable Manufacturing: Environmental Conscious Quality Function Deployment, Life cycle assessment, Design for Environment, R3 and R6 cycles, Design for Disassembly -Sustainable Product Development – Various Phases. Concept of Green manufacturing.

Module III

EIA Methods: CML, EI 95 and 99, ISO 14001 EMS and PAS 2050 standards, Environmental Impact parameters - Interactions between energy and technology and their implications for environment and sustainable development.

Module IV

Design for recycling: Eco friendly product design methods – Methods to infuse sustainability in early product design phases – Multi-Criteria Decision Making in Sustainability, Types, Approaches, Steps, Tools, Applications, Case Studies on MCDM methodologies.

Module V

Frameworks for measuring sustainability: Indicators of sustainability – Environmental, Economic, Societal and Business indicators - Concept Models and Various Approaches, Product Sustainability and Risk/Benefit assessment– Corporate Social Responsibility.

Pre-requisites: NA

Text Books:

1. G. Atkinson, S. Dietz and E. Neumayer, Handbook of Sustainable Manufacturing. Edward Elgar Publishing Limited, 2007.
2. D. Rodick, Industrial Development for the 21st Century: Sustainable Development Perspectives, UN New York, 2007.
3. P. P. Rogers, K. F. Jalal and J. A. Boyd, , An Introduction to Sustainable Development, Earth scan, London, 2007.
4. P. Lawn, Sustainable Development Indicators in Ecological Economics, Edward Elgar Publishing Limited.
5. S. Asefa, The Economics of Sustainable Development, W.E. Upjohn Institute for Employment Research, 2005.

Online Resources:

1. Sustainability through Green Manufacturing Systems: An Applied Approach by Prof. Deepu Philip, Prof. Amandeep Singh , IIT Kanpur.Sustainability through Green Manufacturing Systems: An Applied Approach - Course (nptel.ac.in)

MEC706E Friction Wear and Lubrication 4-0-0

Course Objectives: This course will enable students to:

1. Provide the knowledge and importance of tribology in design
2. Introduce the concept of surface engineering and its importance in tribology
3. Understand the friction, wear and lubrication aspects of machine components

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Course Outcomes: At the end of this course, a student will be able to:

1. Understand and importance of Tribological phenomenon
2. Optimize the friction and wear rate
3. Understand the wear mechanism and types of lubrication

Module I

Introduction: Introduction to Tribology and its historical background, Factors influencing Tribological phenomena of Engineering surfaces

Module II

Surface characterization: Computation of surface parameters, Surface measurement techniques, Apparent and real area of contact, Contact of engineering surfaces - Hertzian and non-hertzian contact, contact pressure and deformation in non-conformal contacts

Module III

Genesis of friction: friction in contacting rough surfaces, sliding and rolling friction, various laws and theory of friction, Stick slip friction behavior, frictional heating and temperature rise, Friction measurement techniques, Friction in tribo-systems, Frictional Devices in mechanical systems.

Module IV

Wear and wear types: Mechanism of wear-adhesive, abrasive, corrosive, erosion, fatigue, fretting, etc., Wear of metals and non-metals, Wear models- asperity contact, constant and variable wear rate, geometrical influence in wear models.

Module V

Wear damage: Wear in various mechanical components, wear controlling techniques, Introduction to lubrication regimes - Boundary Lubrication, Hydrodynamic Lubrication, Elastohydrodynamic Lubrication.

Pre-requisites: Engineering Mechanics, Engineering Design, Fundamentals of Tribology

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Text Books:

1. H. Czichos, A system approach to science and Technology of Friction, Lubrication and Wear, Volume I, Tribology series, Elsevier Publications, 1978.
2. K. C. Ludema, Friction, wear, Lubrication, CRC Press, NY. 1996.

Reference Books:

1. M. B. Peterson and W. O. Winner, Wear control Handbook, sponsored by The Research Committee on Lubrication, 1980.
2. A. Cameron, The principles of Lubrication, Longman, London, 2000.

Online Resources:

1. Friction and wear of materials: principles and case studies by Prof. Dr. B. V Manoj Kumar (IIT Roorkee), NPTEL Course (https://archive.nptel.ac.in/courses/113/108/113108083/).

MEC707E Tribo-Materials 3-0-0

Course Objectives: This course will enable students to:

1. Understand the tribological relevant problems in design
2. Explain the characterization and applications
3. Introduce the concept of surface engineering and its importance in tribology

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Course Outcomes: At the end of this course, a student will be able to:

1. Explain the tribological phenomenon and material properties
2. Explain the wear mechanism based on characterization of tribopairs.
3. Explain the surface treatment techniques and applications

Module I

Introduction: Introduction to tribological processes and tribological relevant properties of material. An overview of engineer materials having potential for tribological application. Selection of materials for tribological applications at design stage.

Module II

Characterization and evaluation of Ferrous material for tribological requirements/application: Selection of ferrous material for rolling elements bearings, gears, crank shafts, piston rings, cylinder liners, etc.

Module III

Characterization and evaluation of Non-Ferrous material for tribological requirements/application: Non-ferrous materials and their applications such e- sliding bearing, piston rings, cylinder liners, etc., materials for dry friction materials. Composite materials (PM, CMC and MMC) for tribological application.

Module IV

Surface treatment techniques with applications: such as carburizing, nitriding, induction hardening, hard facing, laser surface treatments, etc.

Module V

Surface coating techniques: Electrochemical deposition, anodizing, thermal spraying, Chemical Vapour Deposition (CVD), Physical Vapour Deposition (PVD), etc. and their applications.

Pre-requisites: Material Science & Engineering, Fundamentals of Tribology

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Text Books:

1. M. F. Ashby, Materials selection in mechanical design, 4th Edition, Butterworth Heinemann, London, 2010.
2. W. A. Glaeser, Tribology series - Vol. 20," Elsevier Publications, 1992.
3. M. J. Neale, The Tribology Hand Book, Butterworth Heinemann, London, 1995.

Reference Books:

1. M. B. Peterson, and W. O. Winer, , Wear Control Handbook, ASME, NY 1980.
2. V. P. Singh, Mechanical Vibrations, Dhanpat Rai & Company Pvt. Ltd., 2016.

Online Resources:

1. Friction and wear of materials: principles and case studies by Prof. Dr. B. V Manoj Kumar (IIT Roorkee), NPTEL Course (https://archive.nptel.ac.in/courses/113/108/113108083/).

MEC708E **Advanced Fluid Dynamics** **3-0-0**

Course Objectives: This course will enable students to:

1. Learn about the dynamics of viscous flows.
2. Learn aerodynamics of structures
3. Learn about turbulent flows

Course Outcomes: At the end of this course, a student will be able to:

1. Determine the velocity distribution in different viscous flows
2. Apply conservation laws to boundary layer flows
3. Determine lift and drag forces on bodies immersed in fluid
4. Explain the vorticity dynamics in fluid flows
5. Use computational tools to model turbulent flows.

Module I

Viscous Flow: Review of kinematics and dynamics of fluid flows, Exact solutions of N-S equations: flow between two parallel plate, Couette flow, Hagen-Poiseuille flow, flow between two rotating cylinders, Stokes first problem, Stokes second problem.

Module II

Boundary-Layers: Boundary-layer theory, similarity solutions (Falkner-Skan solutions and Blasius solutions), boundary layer integral parameters, Von-Karman momentum integral equation.

Module III

Potential Flow: Basic equations, Elementary and singular solutions in 3D and 2D, methods of superposition of elementary / singular solutions in 3D. Flow past a sphere, applications of lift and drag, flow past immersed bodies: sports ball aerodynamics, aircraft aerodynamics

Module IV

Vorticity Dynamics: Vortex line, vortex tube and vortex filament, rate of change of vorticity of fluid particle,Helmoltz and Kelvin's theorem, velocity induced by a vortex filament, Biot-Savart law, decay of a line vortex in a viscous fluid

Module V

Turbulent Flows: Introduction to turbulence, eddies and vortex shedding, statistical description of turbulent flows, Reynolds stress, RANS, Turbulence modelling : k-ε, k-ω, RMS.

Pre-requisites: NA

Text Books:

1. Kundu, Pijush K., and Ira M. Cohen. Fluid Mechanics. Academic Press.
2. Viscous Fluid Flow, F .M White, McGraw Hill.

Reference Books:

1. Boundary layer theory by H. Schlichting, Springer.

Online Resources:

1. Advanced Fluid Dynamics by Prof. Suman Chakraborty (IIT Kharagpur), NPTEL Course (https://archive.nptel.ac.in/courses/112/105/112105218/).

MEC709E **Advanced Heat Transfer** **3-0-0**

Course Objectives: This course will enable students to:

1. Learn about heat conduction for different geometries
2. Learn about convective heat transfer: free and forced
3. Learn about radiative heat transfer

Course Outcomes: At the end of this course, a student will be able to:

1. Apply generalized heat conduction equation in different scenarios.
2. Apply conservation laws to determine convective heat transfer
3. Determine coefficient of free convection for natural convection heat transfer
4. Explain mechanism of heat transfer for two phase flows
5. Determine radiative heat transfer for different scenarios

Module I

Conduction: Introducing generalized conduction equation for an isotropic in-homogenous solid; concept of isotropic & homogenous conductivity. Exact solution of transient and steady multi-dimensional problems in Cartesian, Cylindrical and spherical geometries

Module II

Generalized Equations of the Boundary layers: Navier–Stokes Equation for 3D flow; 3D Energy Equation, Mass Transfer Equations of Boundary layer, Fundamentals of turbulent heat convection, Heat Transfer in CircularTubes.

Module III

Integral form of Momentum and Energy equations: Over a body of revolution, Solutions for variable free stream velocities over curved surface, free convection heat transfer analysis, Boussinesq approximation

Module IV

Heat Transfer During Phase Change: Generalised equations for two phase heat transfer, Condensation over Vertical and inclined Surfaces, inside and outside cylinders; effect of sub-cooling, Concept of bubble nucleation, growth and detachment, Nucleate Pool boiling, Forced and Natural Convection Boiling, Pressure drop in two phase heat transfer. Heat transfer in porous media.

Module V

Thermal radiation: Radiative properties of non-black surfaces Radiation heat transfer between surfaces: Enclosure theory, View/shape factor relations. Radiation between surfaces with and without participating media. Electric circuit analogy: concept of surface resistance and space resistance, Network of a three-surface enclosure. Radiation exchange with specular surfaces. Formulation for numerical solution. Gas radiation, Introduction to atmospheric radiation

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Pre-requisites: NA

Text Books:

1. J.P. Holman, Heat Transfer , McGraw Hill.
2. Patrick H. Oosthuizen and David Naylor, Introduction to Convective Heat Transfer Analysis, McGraw Hill .

Reference Books:

1. Adrian Bejan, Convective Heat Transfer; John Wiley and Sons.

Online Resources:

1. Advanced Heat and Mass Transfer by Dr Saikat Chakraborty, IIT Kharagpur (https://archive.nptel.ac.in/content/syllabus_pdf/103105052.pdf)

MEC802C **Finite Element Analysis** **3-1-0**

Course Objectives: This course will enable students to:

1. Understand the variational and weighted residual approaches for solving differential equations.
2. Identify the basic finite element concepts and solution procedure.
3. Formulate the element stiffness and mass matrices for various one and two dimensional elements.
4. Formulate and solve the problems using extended finite element approach.

Course Outcomes: At the end of this course, a student will be able to:

1. Solve the differential equations using weighted residual and variational approaches.
2. Apply the steps involved in solving 1D problems using finite element analysis.
3. Solve 2D problems using finite element approach.
4. Solve structural problems related to trusses and frames.
5. Apply the special methods to solve the complex problems.

Module I

Introduction to Finite Element Method: Introduction to finite element method, weak formulations, variational formulations, approximation functions, weighted residual methods, virtual work principle, natural and essential boundary conditions.

Module II

One Dimensional Problems: Discretization of domain, elemental equations, connectivity of elements, interpolation functions and their properties, linear, quadratic and higher order shape functions, assembly of element equations, local and global stiffness matrix and its properties, boundary conditions, solution of equations, applications to solid mechanics, heat transfer and fluid mechanics problems, axisymmetric problems, transient problems.

Module III

Two Dimensional Problems: Single variable problems in 2-D, triangular elements, linear and higher order triangular elements, area coordinates, rectangular elements, higher order rectangular elements, natural coordinates, serendipity elements, numerical integration, master element, coordinate transformations, Jacobian matrix, evaluation of element matrices, boundary integrals, assembly of element equations, post computations, computer implementation.

Module IV

Trusses: Basic truss element, plane truss, local and global coordinate systems, stress calculations, solution of practical problems.

Plane Elastic Problems: Governing equations for plane stress and plane strain, Weak formulations, finite element models for plane elastic problems, evaluation of boundary integrals**.**

Module V

Introduction to Extended Finite Element Method: Concept of strong and weak discontinuities, enrichment functions, stiffness matrix in XFEM, computer implementation

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Pre-requisites:

Text Books:

1. J. N. Reddy , An Introduction to Finite Element Methods, McGraw Hill Education (India).

Reference Books:

1. Fish J. and Belytschko T., A First Course in Finite Elements, John Wiley and Sons.
2. Rao S. S., The Finite Element Method in Engineering, Elsevier Publications.
3. Liu G. R. and Quek S.S., The Finite Element Method; A Practical Course, Butterworth Heinmann.

Online Resources:

1. Basics of Finite Element Analysis - I by Prof. Nachiketa Tiwari (IIT Kanpur), NPTEL Course (https://nptel.ac.in/courses/112104193).
2. Basics of Finite Element Analysis - II by Prof. Nachiketa Tiwari (IIT Kanpur), NPTEL Course (https://nptel.ac.in/courses/112104205).
3. Advanced Finite Element Analysis by Prof. R Krishna Kumar (IITMadras), NPTEL Course (https://archive.nptel.ac.in/courses/112/106/112106130/)

MEC803E Robot Mechanics and Control 3-0-2

Course Objectives: This course will enable students to develop a comprehensive understanding of robotics, covering robot classification, applications, sensor selection, and actuation schemes. It focuses on mastering robot kinematics, including degrees of freedom, coordinate transformations, and DH parameters, alongside matrix methods for kinematic analyses. Additionally, students develop competence in robot dynamics and control, including Euler-Lagrange and Newton-Euler equations and linear control strategies, with practical microcontroller programming experience.

Course Outcomes: At the end of this course, a student will be able to:

1. Demonstrate comprehensive knowledge of robot classification, kinematics, dynamics, and control principles, enabling effective analysis and design of robotic systems.
2. Apply mathematical techniques, including matrix methods and Jacobian analysis, to solve complex problems related to robot motion and manipulation.
3. Utilize programming skills in MATLAB, SIMULINK, and microcontrollers to simulate and implement control strategies for robotic systems, enhancing proficiency in real-time control applications.
4. Engage in hands-on practice sessions to conduct kinematic and dynamic analyses of robot manipulators, develop controller schemes, and gain practical experience in microcontroller programming for efficient robot control.

Module I

Robot Classification: Serial and parallel manipulators, robot selection and application, sensors and actuators, motion and force sensing, actuation schemes: electric, hydraulic and pneumatic.

Module II

Robot Kinematics: Degrees of freedom and mobility, rotation representation, coordinate transformations, DH parameters, matrix methods for forwarded and inverse kinematic analyses, jacobian and singularity.

Module III

Robot Dynamics and Control: SEuler-Lagrange and Newton-Euler equations of motion for robot manipulators, inverse and forward dynamic analyses, linear control of robot manipulators, microcontroller programming.

Module IV

Practice sessions: Kinematic and dynamic analyses of robot manipulators using MATLAB, simulation of controller schemes for robot manipulators using SIMULINK, Introduction to microcontroller programming, robot control using microcontrollers.

Pre-requisites:

Text Books:

1. J. J. Craig, Introduction to Robotics: Mechanics and Control, Pearson
2. M. P. Groover, M. Weiss, R. N. Nagel, and A. Dutta, Industrial Robotics: Technology, Programming, and Applications, McGraw-Hill Education

Reference Books:

1. S. B. Niku, Introduction to Robotics: Analysis, Control, Applications, Wiley
2. B. Siciliano, L. Sciavicco, L. Villani, and G. Oriolo, Robotics: Modeling, Planning and Control, Springer
3. D. B. Marghitu, G. C. Goldammer, and R. E. N. Marghitu, Mechanisms and Robots Analysis with MATLAB®, CRC Press
4. P. Corke, Robotics, Vision and Control: Fundamental Algorithms in MATLAB, Springer
5. L. Joseph, Robot Operating System (ROS) for Absolute Beginners, Apress

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Online Resources:

1. Industrial Robotics : Theories For Implementation, By Prof. Arun Dayal Udai (IIT-ISM Dhanbad), NPTEL Course (https://onlinecourses.nptel.ac.in/noc23_me143/preview).

MEC804E **Advanced Manufacturing System** **3-0-0**

Course Objectives: This course will enable students to develop a comprehensive understanding of advanced manufacturing systems, automation technologies, micro machining, nano machining and fabrication techniques**.**

Course Outcomes: At the end of this course, a student will be able to:

1. Demonstrate proficiency in applying CAD to manufacturing systems and acquire knowledge of various manufacturing technologies, including rapid prototyping.
2. Explain the principles and mechanics of micro/nano machining, and gain expertise in diverse techniques such as abrasive machining, laser machining etc.
3. Gain knowledge of the principles, design, and operation of microelectronic and micromechanical devices.

Module I

Advanced manufacturing system concepts, manufacturing automation, programmable and hard automation, design automation, application of CAD to manufacturing system, design for manufacturing and assembly, computer aided engineering analysis, computer aided engineering evaluation, rapid prototyping, stereolithography, selective laser sintering, FDM, laminated object manufacturing, polyjet technology, robots, their classification and application, introduction to robot programming, PLC's and their applications.

Module II

Introduction to Micro/Nano Machining: Principles of machining, mechanics of micro machining, abrasive micro machining, diamond micro grinding/turning, ultrasonic micro machining, electro-discharge micro machining, laser micro machining, electro-chemical micro machining, ion beam machining, electron beam machining, elastic emission machining, abrasive flow finishing, magnetic abrasive finishing, magneto rheological abrasive flow finishing, magnetic flow polishing.

Module III

Introduction to Micro Fabrication: Micro electronic and micro mechanical devices, crystal growing and wafer preparation, high resolution lithography, diffusion and ion implantation, etching metallization and testing, wire bonding and packaging, yield and reliability of chips, PCB's, the L I G A, micro fabrication process, solid free form fabrication of devices, measuring techniques for micro features, measuring techniques for nano features, micro hardness tester, Laser scanners, robustness and selection of manufacturing processes, factories of future.

Pre-requisites:

Text Books:

1. J. P Davim and M. J. Jackson, Nano and Micromachining, Wiley Publication (2013).
2. M. P. Groover, Fundamentals of Modern Manufacturing: Materials, Processes, and Systems,

Wiley Publication (2013).
3. E. P. Degarmo, J. T. Black and R. A. Kohser, Materials and Processes in Manufacturing, Prentice Hall of India (2006).

Reference Books:

1. S. K. Steven, Manufacturing Processes for Engineering Materials, Prentice Hall of India (2004).
2. V. K. Jain, Micromanufacturing Processes, CRC Press (2012).

Online Resources:

1. Introduction to Mechanical Micromachining by Prof.A M Sidpara (IIT Kharagpur), NPTEL Course (https://archive.nptel.ac.in/courses/112/105/112105231/).
2. Rapid Manufacturing by prof J Ramkumar (IIT, Kanpur), NPTEL Course (https://archive.nptel.ac.in/courses/112/104/112104265/).
3. Fundamentals of micro and nanofabrication By Prof. Shankar Selvaraja and Prof. Sushobhan avasthi (IISc Bangalore), (https://onlinecourses.nptel.ac.in/noc20_bt37/preview)

MEC805E Computational Heat Transfer and Fluid Flow 3-0-2

Course Objectives: This course will enable students to:

1. Learn about mathematical modelling of physical phenomena.
2. Learn about discretization techniques.
3. Learn about modelling of energy systems.

Course Outcomes: At the end of this course, a student will be able to:

1. Explain the different methods of modelling of physical phenomena.
2. Implement discretization techniques to different problems
3. Implement numerical modelling of heat conduction phenomena
4. Implement numerical modelling of fluid flow phenomena
5. Implement numerical modelling of convection phenomena

Module I

Introduction to mathematical modelling: mathematical modelling of physical phenomena, governing differential equations- mass, energy, momentum, nature of coordinates, choice of coordinates.

Module II

Discretization methods: concept of discretization, deriving the discretization equations: Taylor series formulation, variational formulation, method of weighted residuals, control volume formulation.

Module III

Modelling heat conduction: Steady 1-D conduction: equations, grid spacing, source term linearization, boundary conditions, solution of the linear algebraic equations; Unsteady 1-D conduction: general discretization equation, explicit and fully implicit schemes, Crank-Nicholson method, fully implicit discretization; 2-D situations, solution of algebraic equations; Over and under relaxation.

Module IV

Modelling the flow field: Calculation of flow field, vorticity based methods, representation of pressure-gradient, representation of the continuity equation, staggered grids, momentum equation, pressure and velocity corrections, SIMPLE algorithm, SIMPLER algorithm.

Module V

Modelling convection and diffusion: Steady 1-D convection and diffusion: preliminary derivation, upwind scheme, exponential scheme, hybrid scheme, power law scheme, discretization for 2-D, oneway space coordinate, false diffusion.

Pre-requisites: NA

Text Books:

1. Patankar S.V., Numerical Heat Transfer and Fluid Flow, Hemisphere Series on

Computational Methods in Mechanics and Thermal Science.
2. Muralidhar K., Sundararajan T., Computational Fluid Flow and Heat Transfer, Narosa Publications.

Reference Books:

1. P. Moin, Fundamentals of Engineering Numerical Analysis, Cambridge University Press.

Online Resources:

1. Computational Fluid Dynamics by Prof. S Chakraborty (IIT Kharagpur), NPTEL Course (https://nptel.ac.in/courses/112105045).
2. Computational Fluid Dynamics and Heat Transfer by Prof Gautam Biswas (IIT Kanpur), NPTEL Course (https://onlinecourses.nptel.ac.in/noc22_me101/preview).
