COURSES OF STUDY FOR

M. TECH.

INDUSTRIAL TRIBOLOGY & MAINTENANCE MANAGEMENT (ITMM)

IN

MECHANICAL ENGINEERING

(Effective From – Admission Batch 2021)

DEPARTMENT OF MECHANICAL ENGINEERING

NATIONAL INSTITUTE OF TECHNOLOGY SRINAGAR

Hazratbal, Srinagar, J&K – 190006 - India

Vision and Mission of the Department

VISION

To nurture Mechanical Engineers with a passion for professional excellence, who are ready to take on global challenges and serve the society with high human values.

MISSION

M1: To provide facilities and infrastructure for academic excellence in the field of Mechanical Engineering.
M2: To inculcate in the students a passion for understanding professionalism, ethics, safety, and sustainability, and enable them to contribute to the society.
M3: To nurture creativity of the students and encourage them to come up with innovative solutions to real life problems.
M4: To prepare the student for lifelong learning with global perspective.

Brief about the Department:

Established in the year 1963, the Department of Mechanical Engineering offers a unique opportunity in terms providing first-class pedagogy and world class facilities for conducting cutting-edge research. Being one of the oldest departments of NIT Srinagar, the department has evolved into one of the finest in terms of teaching curriculum and methodology supported by a well-organized and adequately funded research program. We have a very well-established B. Tech program complemented by three M. Tech programs in Mechanical System Design, Industrial Tribology & Maintenance Management and Thermal Engineering. The masters' students are admitted on the basis of a valid GATE score, and some additional seats are reserved for meritorious sponsored candidates. The Research Scholars (PhD) are admitted to the department every year on the basis of a rigorous examination conducted by the institute.

Our curriculum is designed to cater to the needs and aspirations of the industry, and our top class faculty ensures that the students acquire the necessary technical and decision making skills to be the leaders in the dynamic world of industry.

Our department is, perhaps, the most versatile in terms of the range of specializations of its faculty members. We have faculty members who specialize in Haptics and MEMS on one end to High-temperature Tribology, Manufacturing Strategies and Quality Control on the other. The traditional areas of Mechanical Engineering such as Machine Design, Fluid Mechanics and Thermal Sciences are also well-represented. The department has a very strong group working in the area of Friction, Lubrication and Wear, with state-of-the-art research facilities and equipment. Our academic curriculum has improved considerably with the passage of time. Regular Board of Studies meetings are conducted to remove any inadvertent deficiencies. Periodic feedback is taken from the students to improve the quality of the education imparted. Feedback is also taken from the visiting companies during the placement season to orient the curriculum towards the needs of the Industry. Specialized courses are floated to cater to the needs of the PhD scholars, preparing them for subsequent research.

We strive to produce engineering graduates of high quality who are team players, accountable, resourceful and above all, technically competent. I take this opportunity to invite prospective students to our department and benefit from our experienced and wonderful talent pool. Our faculty and staff, I am sure, will deliver with unmatched dedication and professional enthusiasm.

List of Programs offered by the Department:

- Bachelor of Technology (B. Tech.) in Mechanical Engineering
- Master of Technology (M. Tech.) in Industrial Tribology & Maintenance Management (ITMM)
- Master of Technology (M. Tech.) in Mechanical System Design(MSD)
- Master of Technology (M. Tech.) in Thermal Engineering
- Doctor of Philosophy (Ph.D.)

Contents

Credit Scheme

Program	Semester-wise credit distribution				Total Credits
	1st	2nd	3rd	4th	
M. Tech ITMM (Mechanical Engineering)	16	16	16	12	60

As per NIT Srinagar Academic Statutes, a student has to complete a minimum of **60 credits** for the award of M.Tech Degree. The credit structure is as follows:

Core Courses	Elective Courses	Dissertation Work
10 Courses (30 Credits)	4 Courses (12 Credits)	D-I & D-II (18 Credits)

1. Full time duration: 2 years
2. Part time duration: 3 years.
3. Full time student has to take 12 to 18 credits in each semester.
4. Part time student has to take 9 to 12 credits in each semester.

List of Courses Offered

S. No.	Course Title	Course Category
01	Fundamentals of Tribology	Core
02	Tribological Materials	
03	Design Optimization	
04	Reliability, Availability, Maintainability, and Safety	
05	Diagnostic Maintenance and Condition Monitoring	
06	Design and Analysis of Experiments	
07	Lubricant Selection and Applications	
08	Wear Analysis and Control	
09	Design of Tribological Components	
10	Design for Maintenance	
20	Bearing Design	Elective
21	Value Engineering	
22	Automation and Control	
23	Tribology in Machine Design	
24	Surface Engineering	
25	Corrosion and Corrosion Protection	
26	Operations Research	
27	Composite Materials	
28	Finite Element Method	
29	Modeling and Simulation of Dynamical Systems	
30	Computer Applications in Maintenance	
31	Advanced Manufacturing Systems	
31	Tribology Laboratory-I	Laboratory
32	Tribology Laboratory-II	

National Institute of Technology Srinagar
Department of Mechanical Engineering

Semester-Wise Course Scheme

M.Tech (ITMM) 1st Semester

S. No	Course Code	Course Title	Hours Per Week			Total Contact Hours	Credits
			L	T	P		
1	TMMM-101	Fundamentals of Tribology	3	0	0	3	3
2	TMMM-102	Tribological Materials	3	0	0	3	3
3	MSDM-103	Design Optimization	3	0	0	3	3
4	TMMM-103	Reliability, Availability, Maintainability, and Safety	3	0	0	3	3
5	TMMM-104	Elective-I	3	0	0	3	3
6	TMMM-105	Tribology Laboratory-I	0	0	2	2	1
Total			**15**	**00**	**02**	**17**	**16**

M.Tech (ITMM) 2nd Semester

S. No	Course Code	Course Title	Hours Per Week			Total Contact Hours	Credits
			L	T	P		
1	TMMM-201	Diagnostic Maintenance and Condition Monitoring	3	0	0	3	3
2	TMMM-202	Design and Analysis of Experiments	3	0	0	3	3
3	TMMM-203	Lubricant Selection and Applications	3	0	0	3	3
4	TMMM-204	Wear Analysis and Control	3	0	0	3	3
5	TMMM-205	Elective-II	3	0	0	3	3
6	TMMM-206	Seminar	0	0	2	2	1
Total			**15**	**00**	**02**	**17**	**16**

M.Tech (ITMM) 3rd Semester

S. No	Course Code	Course Title	Hours Per Week			Total Contact Hours	Credits
			L	T	P		
1	TMMM-301	Design of Tribological Components	3	0	0	3	3
2	TMMM-302	Design for Maintenance	3	0	0	3	3
3	TMMM-303	Tribology Laboratory-II	0	0	2	2	1
4	TMMM-304	Dissertation-I	0	0	12	12	6
5	TMMM-305	Elective-III	3	0	0	3	3
Total			**9**	**00**	**14**	**23**	**16**

M.Tech (ITMM) 4th Semester

S. No	Course Code	Course Title	Hours Per Week			Total Contact Hours	Credits
			L	T	P		
1	TMMM-401	Dissertation-II	0	0	24	24	12
Total			**0**	**0**	**24**	**24**	**12**

Semester-Wise Elective Options

Semester – 1st	**Semester – 2nd**	**Semester – 3rd**
Elective-I (TMMM-104*)	**Elective-II (TMMM-205*)**	**Elective-III (TMMM-305*)**
Bearing Design	Surface Engineering	Finite Element Method
Value Engineering	Corrosion and Corrosion Protection	Modeling and Simulation of Dynamical Systems
Automation and Control	Operations Research	Computer Applications in Maintenance
Tribology in Machine Design	Composite Materials	Advanced Manufacturing Systems

Detailed Curriculum for 1st Year – 1st Semester Courses

Subject: Fundamentals of Tribology (Code: TMMM-101)	**Year and Semester: 1st Year and 1st Semester**		**Total Course Credit: 3**		
			L	T	P
			3	0	0
Evaluation Policy	Mid-Term	Continuous Assessment	End-Term		
	26 Marks	24 Marks	50 Marks		

Detailed Syllabus:

UNIT I
Introduction to Tribology and its historical background, Factors Influencing Tribological phenomena, Engineering surfaces - 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.

UNIT II
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.

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

Text Books:

1. Czichos, H., A system approach to science and Technology of Friction, Lubrication and Wear Volume I, Tribology series, Elsevier Publications, 1978.
2. Ludema, K.C., Friction, wear, Lubrication, CRC Press, NY., 1996.
3. Gwidon Stachowiak, Andrew W Batchelor, Engineering Tribology, Butterworth Heinemann, 4th Edition, 2016, ISBN 978-0128100318.

Reference Books:

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

Subject: Tribological Materials (Code: TMMM-102)	**Year and Semester: 1st Year and 1st Semester**		**Total Course Credit: 3**		
			L	T	P
			3	0	0
Evaluation Policy	Mid-Term	Continuous Assessment	End-Term		
	26 Marks	24 Marks	50 Marks		

Detailed Syllabus:

UNIT I
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.

UNIT 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. Non-ferrous materials and their applications such as sliding bearing, piston rings, cylinder liners, etc., materials for dry friction materials, Composite materials (PM, CMC and MMC) for tribological application.

UNIT III
Surface treatment techniques with applications such as carburizing, nit riding, induction hardening, hard facing, laser surface treatments, etc., Surface coating techniques such as electrochemical deposition, anodizing, thermal spraying, Chemical Vapour Deposition (CVD), Physical Vapour Deposition (PVD), etc. and their applications.
Lubricants- Introduction, requirements, types, Evaluation and testing of lubricants.

Text Books:

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

Reference Book:

1. P. Peterson, M. B., Winer, W.O., Wear Control Handbook, *ASME, NY. 1980*.

Subject: Design Optimization (Code: MSDM-103)	**Year and Semester: 1st Year and 1st Semester**		**Total Course Credit: 3**		
			L	T	P
			3	0	0
Evaluation Policy	Mid-Term	Continuous Assessment	End-Term		
	26 Marks	24 Marks	50 Marks		

Detailed Syllabus:

UNIT I: Classical Optimization Theory

Nonlinear Optimization Techniques, Single-Variable Optimization, Multivariable Optimization, Unconstrained Problems, Necessary and Sufficient Conditions, the Hessian matrix, Semi-definite Cases, Saddle Points, Multivariable Optimization with Equality Constraints, Solution by Direct Substitution, Method of Constrained Variation, Solution by the Method of Lagrange Multipliers, Equality Constraints and the Bordered Hessian, Basics of Convex Programming, Multivariable Optimization with Inequality Constraints, Slack Variables, Constraint Qualification, Karush Kuhn Tucker (KKT) Conditions, Regularity, Convexity, Convex Programming Problems, Use of the Optimization Toolbox in MATLAB® to solve unconstrained and constrained optimization problems.

UNIT II: Calculus of Variations

Introduction to the Calculus of Variations, Fundamental lemma of Calculus of Variations, Functionals, Examples of Simple Functionals, The First Variation, First Variation with Several Dependent Variables, The Euler-Lagrange equation, Applications and Extensions of the Euler-Lagrange equation, Isoperimetric problems, Functional Constraints, Applications involving the optimization of a functional subject to constraints, Functionals involving Higher-Order Derivatives, Applications in Mechanics, Variational Formulations, Strong and Weak forms of Governing equations, the Principle of Minimum Potential Energy, Dynamics of particles, Hamilton's principle and its applications.

UNIT III: Structural Optimization

Introduction to Structural Optimization, General Mathematical Form of a Structural Optimization Problem, Size Optimization of an axially loaded bar for maximum stiffness, Mean compliance, Beam design for stiffness and strength, Optimal design of a beam for given deflection.

Text Books:

There is no single textbook that can be prescribed for this course. You shall have to rely on class notes and the reference books mentioned below.

Reference Books:

1. S. S. Rao, Engineering Optimization, Theory and Practice, Fourth Edition, John Wiley and Sons.
2. Robert Weinstock, Calculus of Variations with Applications to Physics and Engineering, Dover publications, 1974.
3. Peter W. Christensen, Anders Klarbring, An Introduction to Structural Optimization, 2009 Springer Science and Business Media B.V., ISBN 978-1-4020-8665-6.
4. M.P. Bendsoe, O. Sigmund, Topology Optimization: Theory, Methods, and Applications, Springer-Verlag, Berlin Heidelberg.

Subject: Reliability, Availability, Maintainability, and Safety (Code: TMMM-103)	**Year and Semester: 1st Year and 1st Semester**		**Total Course Credit: 3**		
			L	T	P
			3	0	0
Evaluation Policy	Mid-Term	Continuous Assessment	End-Term		
	26 Marks	24 Marks	50 Marks		

Detailed Syllabus:

UNIT I

Evolution of maintenance, objective of maintenance, maintenance policies and philosophies, maintenance concept, maintenance management & terotechnology, relationship with other functional areas, importance of maintenance, elements of good maintenance, economics of maintenance, training and safety aspects in maintenance.

Classification of maintenance programs, corrective preventive and predictive maintenance, comparison of maintenance programs, preventive maintenance- concept, functions, benefits, limitations

UNIT II

Condition based maintenance (CBM) techniques, manual inspections, performance monitoring, vibration monitoring, current monitoring, coil debris/spectroscopy, thermography and corrosion monitoring, steps in implementation of CBM, benefits of CBM, Reliability centered maintenance(RCM) RCM logic, benefits of RCM, introduction to Total productive maintenance (TPM), , Objectives, key supporting elements of TPM, methodology, evaluation and benefits.

UNIT III

Introduction to Reliability, Techniques for improvement of operational reliability, Reliability calculations, safety and availability of machines and production systems, maintainability criteria, checklist to assess the maintainability of a system, maintainability programs, objectives, key issues in availability improvements program, fault diagnosis, Pareto principle Ishikawa diagram.

Text Book:

1. Duffuaa, S. O. and Raouf, A., Planning and control of maintenance Systems: Modeling and Analysis, John Wiley Inc., 1999.

Reference Books:

1. Higgin L.R., Maintenance Planning and Control, McGraw-Hill Book Co., 1990.
2. Kelly Anthony, Maintenance Planning and Control, East West Press Private Ltd, New Delhi, 1991.
3. Blanchard B.S. and Lowey E.E., Maintainability principle and practices, McGraw-Hill Book Co.
4. Niebel Benjamin W. Marcel Dekher, Engineering Maintenance Management, 1994.

Subject: Tribology Laboratory-I (Code: TMMM-105)	**Year and Semester: 1st Year and 1st Semester**	**Total Course Credit: 1**		
		L	T	P
		0	0	2
Evaluation Policy	Continuous Assessment	End-Term		
	60 Marks	40 Marks		

List of Experiments:

S. No.	Experiment
01	Polishing of samples using manual and automatic methods
02	Preparation of samples using an automatic pneumatic mounting press
03	Determination of hardness of prepared samples using a microhardness tester
04	Examination of surface morphology of prepared samples using an optical microscope
05	Preparation and testing of lubricants using a four-ball tester

Detailed Curriculum for 1st Year – 2nd Semester Courses

Subject: Diagnostic Maintenance and Condition Monitoring (Code: TMMM-201)	**Year and Semester: 1st Year and 2nd Semester**		**Total Course Credit: 3**		
			L	T	P
			3	0	0
Evaluation Policy	Mid-Term	Continuous Assessment	End-Term		
	26 Marks	24 Marks	50 Marks		

Detailed Syllabus:

UNIT I
Introduction to condition based Maintenance (CBM), condition monitoring (CM) and the integrity of industrial systems, CM & Diagnostic Engineering management, Economic justification and benefits, Market Research, Techniques for visual inspection.

UNIT II
Application and economic benefits, Signature analysis - online and off-line techniques, Noise measurement, Various condition Monitoring (CM) techniques – Acoustic cross correlation, Acoustic emission, Coating thickness, Dye penetrant examination, Eddy current testing, Magnetic plugs, Magnetic particle examination, Thermography, Ultrasonics.
Vibration monitoring and analysis, Measuring vibration, Frequency, Phase and vibration analysis.

UNIT III
Oil analysis including wear debris and contaminant monitoring, Ferrography, Spectrometric oil analysis program, Performance monitoring, Practical applications of diagnostic maintenance, Condition monitoring of mechanical and electrical machines.

Text Book:

1. Willaims, J.H., Davies, A. and Drake, P, Condition based maintenance & Machine diagnostics, Chapman & Hall, 1st Edition, London, 1994.

Reference Books:

1. K Davies, A., handbook of condition monitoring, Chapman & Hall, London, 1998.
2. Higgins, L.R. and Morrow, L.C., Maintenance Engineering H/B, McGraw Hill, NY, 1977.

Subject: Design and Analysis of Experiments (Code: TMMM-202)	**Year and Semester: 1st Year and 2nd Semester**		**Total Course Credit: 3**		
			L	T	P
			3	0	0
Evaluation Policy	Mid-Term	Continuous Assessment	End-Term		
	26 Marks	24 Marks	50 Marks		

Detailed Syllabus:

UNIT I
Determining central tendency using various methods: Mean, Median and Mode, Sampling and Sampling Distribution, Standard Deviation, Variance, Basic statistical concepts, Hypothesis testing, Confidence intervals, Strategy of experimentation, basic principles, guidelines for designing experiments, Simple comparative experiments: randomized designs, Experiments with a single factor: The Analysis of variance, Analysis of the fixed effects model, practical interpretation of results.

UNIT II
Randomized Blocks, Latin Squares & Related designs: Randomized complete block designs, Latin Square design, Factorial design: Basic definitions and principles, the two-factor factorial designs, statistical analysis of the fixed effects model, estimating the model parameters, the assumption of no-interaction in a two-factor model.

UNIT III
The general factorial design, 2^k factorial designs: The 2^2 design, the 2^3 design, the General 2^k factorial design, Two level fractional factorial design: Introduction; the one half fraction of the 2^k design; the one quarter fraction of the 2^k design; the 3^2 design, the 3^3 design; the Taguchi design: orthogonal array, signal-to-noise ratio, analysis of variance, Examples of L_8 and L_9 Taguchi design.

UNIT IV
Fitting regression models: Introduction; multiple linear regression models; estimation of the parameters in linear regression models; Hypothesis testing in multiple regressions, test for significance of the regression, Response surface methodology, computer-based data analysis.

Text Book:

1. Montgomery Douglas C. (2005, 2008), Design & Analysis of Experiments, 5th Ed. John Wiley and Sons, New York.

Reference Books:

1. Richard L. Levin and David S. Ruben, Statistics for Management, Hall of India Pvt. Ltd., New Delhi.
2. Angela M. Dean and Daniel Voss (2000), Design and Analysis of Experiments, Springer, NY.
3. Jiju Antony (2003), Design of Experiments for Engineers and Scientists. 1st Ed. Butterworth-Heinemann.
4. Hines and Montgomery. (1990), Probability and Statistics for Engineers, John Wiley and Sons, NY.

Subject: Lubricant Selection and Applications (Code: TMMM-203)	**Year and Semester: 1st Year and 2nd Semester**		**Total Course Credit: 3**		
			L	T	P
			3	0	0
Evaluation Policy	Mid-Term	Continuous Assessment	End-Term		
	26 Marks	24 Marks	50 Marks		

Detailed Syllabus:

UNIT I

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 Disiloxanes, 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.

UNIT 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, Molybdenum disulphide composites, graphite composites, calcium fluoride composites, physical and chemical properties of lubricants.

UNIT 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.

Text Books:

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

Reference Book:

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

Subject: Wear Analysis and Control (Code: TMMM-204)	**Year and Semester: 1st Year and 2nd Semester**		**Total Course Credit: 3**		
			L	T	P
			3	0	0
Evaluation Policy	Mid-Term	Continuous Assessment	End-Term		
	26 Marks	24 Marks	50 Marks		

Detailed Syllabus:

UNIT I
Introduction to wear control, types of wear, Adhesive wear, two-body and three-body abrasive wear, erosive wear, cavitation wear, etc., Tribo systems and tribo-elements, Measurement of Surface roughness Re, Rz, Experimental studies on friction on various tribo systems using pin-on-ring (POR) and pin-on-disc (POD) machines etc., Sample preparation, wear measurement of various tribo-elements using POR and POD machines, Calculation of wear volume and wear coefficient, comparison with existing data.

UNIT II
Diagnosis of wear mechanism using optical microscopy and scanning electron microscopy etc., Wear resistant materials, wear resistant coatings, eco-friendly coatings designing for wear, systematic wear analysis, wear coefficients, filtration for wear control.

UNIT III
Component wear, bushings, lubricated piston rings and cylinder bore wear, dry piston rings, rolling bearings, seal wear, gear wear, gear couplings, wear of brake materials, wear of cutting tools, chain wear. Boundary lubrication, Hydrodynamic lubrication, EHD lubrication.
With case studies.

Text Books:

1. Czichos, H., Tribology: A system approach to the science & technology of friction, lubrication and wear, Series 1, *Elsevier Publications 1982*.
2. Glaeser, W. A., Tribology series - Vol. 20, *Elsevier Publications, 1992.*
3. Neale, M.J., The Tribology Hand Book, *Butterworth Heinemann, London, 1995*.

Reference Book:

1. Peterson, M. B., Winer, W.O., Wear Control Handbook, *ASME, NY. 1980*.

Detailed Curriculum for 2nd Year – 3rd Semester Courses

Subject: Design of Tribological Components (Code: TMMM-301)	**Year and Semester: 2nd Year and 3rd Semester**		**Total Course Credit: 3**		
			L	T	P
			3	0	0
Evaluation Policy	Mid-Term	Continuous Assessment	End-Term		
	26 Marks	24 Marks	50 Marks		

Detailed Syllabus:

UNIT I
Application of system concepts to tribology, Function of Tribomechanical systems, Structure of Tribo-mechanical systems, Tribological interaction, Functional plane, mechanical work plane, thermal plane and material plane, Role of tribo process in mechanical systems, Wear as system property, Contact Mechanics, number of bodies taking part in contact process, macro geometry of bodies, Deformation mode, elastic, plastic elastic-plastic, Types of relative motion, static contact, rolling contact, sliding contact, contact physics and geometry, contamination layer, absorbed gas layer, oxide layer, work hardened layer metal substrate.

UNIT II
Materials for various tribo-components, materials for plane bearing, materials for gear, materials for brakes, clutches, materials for Internal combustion engines, ceramics and special alloys, cermets, polymer materials, selection considerations in design.

UNIT III
Design of various tribo-elements such as Plane bearing, Gear, Seals, Piston and cylinder, Friction devices, cutting tools, chains, Design of lubrication systems.

Text Book:

1. D Czichos, H., Tribology: A system approach to the science & technology of friction, lubrication and wear, Tribology Series 1, Elsevier Scientific Publishing Company, Amsterdam, Oxford, New York, 1978.

Reference Books:

1. Peterson, M. B., Winer, W. O., Wear Control Handbook, ASME, N. Y., 1992.
2. Glaeser, W. A., Tribology: Materials for Tribology, Tribology series - Vol. 20, Elsevier, N. Y. 1992.
3. Stolarski, T., Tribology in Machine Design, Butterworth-Heinemann, N. Y.,1990.

Subject: Design for Maintenance (Code: TMMM-302)	**Year and Semester: 2nd Year and 3rd Semester**		**Total Course Credit: 3**		
			L	T	P
			3	0	0
Evaluation Policy	Mid-Term	Continuous Assessment	End-Term		
	26 Marks	24 Marks	50 Marks		

Detailed Syllabus:

UNIT I
Overview of Maintenance, System Approach to Maintenance & Maintainability, Systematic design Approach to Maintainability, Maintainability at System conceptual design Stage (CDS), Introduction to Graph theory and fuzzy decision making at CDS for Maintainability.

UNIT II
Identification of Maintainability Parameters/attributes, Accessibility of critical components, Diagnosability, identification & Isolation of fault, Built in diagnostic for fault detention Optimum selection of maintenance systems, Design for condition monitoring, Design of Plant and machinery for a given maintenance strategy, Design for environment friendly maintenance, Standardization and interchangeability.

UNIT III
Life cycle costing for optimum design and selection, Maintenance Logistics (facilities and resources), Human and safety factor, Design for maintenance through internet based technology (on-site and off-site), Developing reliable maintenance system, Design for simplicity and ease of maintenance, Design complexity versus maintenance complexity for enhanced availability, Fail safe design, FMEA, FMECA for design of failure free systems, Case studied from industries .
Industrial visits

Text Book:

1. Dhillon, B.S., Engineering Maintainability, Gulf publishing company, Houston Texas, USA, 1999.

Reference Book:

1. Higgins, L.R. and Morrow, L.C., Maintenance Engineering H/B, McGraw Hill, NY, 1977.

Subject: Tribology Laboratory-II (Code: TMMM-303)	**Year and Semester: 2nd Year and 3rd Semester**	**Total Course Credit: 1**		
		L	T	P
		0	0	2
Evaluation Policy	Continuous Assessment	End-Term		
	60 Marks	40 Marks		

List of Experiments:

S. No.	**Experiment**
01	Rheological analysis of a synthesized lubricant
02	Determination of the coefficient of friction for a sliding test using a universal tribometer
03	Wear analysis of a sliding test sample using an optical microscope and FESEM
04	Determination of the coefficient of friction for a fretting test using a universal tribometer
05	Wear analysis of a fretting test sample using an optical microscope and FESEM

List of elective courses

S. No.	Course Code	Course Title	L	T	P	Total Contact Hours	Credits
1	TMMM-104*	Bearing Design	3	0	0	3	3
2	TMMM-104*	Value Engineering	3	0	0	3	3
3	TMMM-104*	Automation and Control	3	0	0	3	3
4	TMMM-104*	Tribology in Machine Design	3	0	0	3	3
5	TMMM-205*	Surface Engineering	3	0	0	3	3
6	TMMM-205*	Corrosion and Corrosion Protection	3	0	0	3	3
7	TMMM-205*	Operations Research	3	0	0	3	3
8	TMMM-205*	Composite Materials	3	0	0	3	3
9	TMMM-305*	Finite Element Method	3	0	0	3	3
10	TMMM-305*	Modeling and Simulation of Dynamical Systems	3	0	0	3	3
11	TMMM-305*	Computer Applications in Maintenance	3	0	0	3	3
12	TMMM-305*	Advanced Manufacturing Systems	3	0	0	3	3

Detailed Curriculum for Elective Courses

Subject: Value Engineering (Code: TMMM-104*)	**Year and Semester: 1st Year and 1st Semester**		**Total Course Credit: 3**		
			L	T	P
			3	0	0
Evaluation Policy	Mid-Term	Continuous Assessment	End-Term		
	26 Marks	24 Marks	50 Marks		

Detailed Syllabus:

UNIT I
Introduction to Value Engineering (VE) & value analysis, Life Cycle of a product, Methodology of VE, reasons for the existence of unnecessary costs, Quantitative definition of value, use value and prestige value, Estimation of product quality/performance, types of functions, relationship between use functions and esteem functions in product design, functional cost and functional worth, effect of value improvement on profitability, Tests for poor value, Aims of VE systematic approach.

UNIT II
Elementary introduction to VE job plan/ functional approach to value improvement, various phases and techniques of the job plan, factors governing project selection, types of projects, Life Cycle Costing (LCC) for managing the total value, concepts in LCC, present value concept, annuity concept, net present value, pay back period, Internal rate of return on investment (IRR), Examples and illustrations, creative thinking and creative judgement, positive or constructive discontent, tangible and intangible costs of implementation, false material, labour and overhead saving, VE/VA yardsticks, relationship between savings and probability of success, reliability estimation, system reliability, reliability elements in series and parallel.

UNIT III
Phases and Techniques of VE Job Plan:
General phase, information phase, function phase, creativity/speculation phase, evaluation phase, investigation phase and recommendation phase**:** value improvement recommendation theory, determination of Cut-off Point (COP), road blocks in implementation, decision matrix/evaluation matrix, quantitative comparison of alternatives, estimation of weights factors and efficiencies, utility transformation functions, bench marking, perturbation of weight factors (sensitive, analysis), examples, fast diagramming: critical path of functions, how, why & when logic, supporting and all time functions.
Term paper on recent advances in the field.

Text Books:

1. Arthur E. Mudge, Value Engineering - A Systematic Approach, McGraw Hill Book Co. 1971.

Reference Books:

1. Miles L.D., Techniques of value Analysis and Engineering, McGraw Hill Book Co. New York, 1970.
2. ASTME-American society for Tool and Manufacturing Engineers, Value engineering in Manufacturing, Prentice Hall Inc. 1967.

Subject: Corrosion and Corrosion Protection (Code: TMMM-205*)	**Year and Semester: 1st Year and 2nd Semester**		**Total Course Credit: 3**		
			L	T	P
			3	0	0
Evaluation Policy	Mid-Term	Continuous Assessment	End-Term		
	26 Marks	24 Marks	50 Marks		

Detailed Syllabus:

UNIT I
Importance of corrosion control in industrial practices, Thermodynamics of corrosion, Broad forms of corrosion - uniform, uneven, pitting, cracking, etc., Influencing factors on corrosion, Surface film, Polarization and effects, Theory of passivity, Kinetics of corrosion, Broad forms of corrosion-uniform, uneven, putting, cracking, etc., Influencing factors on corrosion, Surface film, Polarisation an effect, Theory of passivity, Kinetics of corrosion.

UNIT II
Various types of corrosion along with case studies - Galvanic, Thermo-galvanic, High temperature corrosion, Intergranular, Pitting, Selective attach (leaching), Fretting corrosion-erosion, Cavitations, Stress corrosion cracking, Hydrogen embitterment.

UNIT III
Tribo-corrosion, Corrosion fatigue and Corrosive wear, Application of Non Destructive Techniques (NDT) for corrosion evaluation and monitoring, Corrosion Control - Design improvement, Selection of material, fabrication processes for corrosion control, Role of residual stresses, Changes in operating conditions, Use of inhibitors, Anodic and cathodic protection, Corrosion resistant coating, Case studies.

Text Book:

1. Revie, R W., Corrosion and corrosion control, John Wiley & Sons, 4th Edition, NJ., USA, 2008.

Reference Book:

1. Revie, R W., Uhligs Corrosion Hand Book, John Wiley & Sons, 3rd Edition, NJ., USA, 2011.

Subject: Finite Element Method (Code: TMMM-305*)	**Year and Semester: 2nd Year and 3rd Semester**		**Total Course Credit: 3**		
			L	T	P
			3	0	0
Evaluation Policy	Mid-Term	Continuous Assessment	End-Term		
	26 Marks	24 Marks	50 Marks		

Detailed Syllabus:

UNIT I

Physical problems and finite element method (FEM), simulations and visualizations in FEM, Integral formulations for numerical solutions, Variational method, sub-domain method, collocation, Galerkin's method, least squares method, element matrices, Analysis of beams, trusses, one dimensional formulations, two dimensional formulations, Co-ordinate systems, local, global and natural, area coordinates and continuity, strong and weak forms, Hamilton's principle, domain discretization, properties of shape functions, shape functions for trusses.

UNIT II

Strain matrices and element matrices in local and global coordinates for trusses and beams, Rate of convergence and high-order one dimensional elements, Use of commercial code for specific problems on beams and trusses, FEM for frames, Case study of a typical frame e.g., a bicycle, FEM for 2-D solids, construction of shape functions for 2-D elements, strain matrix and element matrices for 2-D elements, linear rectangular element and shape function construction, Gauss integration, Linear quadrilateral elements and coordinate mapping.

UNIT III

Quadratic and cubic triangular elements, rectangular elements and Lagrange elements, Serendipity type of elements and elements with curved edges, FEM for plates and shells, Shape functions and element matrices for plates and shells, elements in local and global coordinate systems for plates and shells, some specific case study on plates and shells using a commercial code, FEM for 3-D solids, meshing and solution procedures.

Text Book:

1. J.N.Reddy, Introduction to the Finite Element Method, 4th Ed., McGraw-Hill, 2019.

Reference Books:

1. Kenneth H. Huebner, Donald L. Dewhirst, Douglas E. Smith, and Ted G. Byrom, The Finite Element Method for Engineers, 4th Ed., Wiley, 2001.
2. O.C.Zienkiewicz, R. L. Taylor, and J. Z. Zhu, The Finite Element Method: Its Basis and Fundamentals, 7th Ed., Elsevier, 2013.

Subject: Computer Applications in Maintenance (Code: TMMM-305*)	**Year and Semester: 2nd Year and 3rd Semester**		**Total Course Credit: 3**		
			L	T	P
			3	0	0
Evaluation Policy	Mid-Term	Continuous Assessment	End-Term		
	26 Marks	24 Marks	50 Marks		

Detailed Syllabus:

UNIT I
Introduction to information systems, Maintenance Management Information system (MMIS), System analysis and design, Role of computer in maintenance management, Maintenance overview.

UNIT II
Basics of software engineering, Fundamentals of Programming with specific emphasis of object oriented paradigms, Study of various available software and their implementation for maintenance, System analysis of various maintenance strategies, activities/modules and their implementation.

UNIT III
Evaluation and optimum selection of computerized maintenance management system (CMMS), Knowledge based approach to maintenance management, Neural network for CMMS, Software consideration for design of CMMS, Maintenance through internet based technology, Case studies.

Text Books:

1. Willaims, J.H., Davies, A. and Drake, P, Condition based maintenance & Machine diagnostics, Chapman & Hall, 1st Edition, London, 1994.

Reference Books:

1. Higgins, L.R. and Morrow, L.C., Maintenance Engineering H/B, McGraw Hill, NY, 1977.

Subject: Advanced Manufacturing Systems (Code: TMMM-305*)	**Year and Semester: 2nd Year and 3rd Semester**		**Total Course Credit: 3**		
			L	T	P
			3	0	0
Evaluation Policy	Mid-Term	Continuous Assessment	End-Term		
	26 Marks	24 Marks	50 Marks		

Detailed Syllabus:

UNIT I
Advanced manufacturing system concepts, Manufacturing automation, types of automations, Application of CAD to manufacturing systems, Design for manufacturing and assembly, Materials handling equipment.

UNIT II
Introduction to CNC programming, Computer Integrated Manufacturing Systems, Robots, their classifications and applications, Introduction to Industry 4.0 and 5.0. Rapid Prototyping and Additive Manufacturing.

UNIT III
Advances in Machining: High speed machining, Introduction to Micro/ Nano machining, Abrasive Micro machining, Diamond Micro- grinding/turning, Ultrasonic Micromachining, Electric-discharge Micro-machining, Laser beam machining, Ion Beam Machining, Electron Beam Machining.

UNIT IV
Introduction to Micro fabrication: High resolution lithography, Measuring techniques for nano features, Microhardness tester, Factories of the future, Advances in forming: Electro-hydraulic forming, Electro-magnetic forming, Hydro forming, Surface coating: Chemical vapour deposition, and physical vapour deposition.

Text Books:

1. Degarmo, E.P., Black, J.T. and Kohser, R.A, Materials and Processes in Manufacturing, Prentice Hall of India, 2006.
2. Amitabh Ghosh and Ashok Kumar Mallick, Manufacturing Science, Pearson, 3rd edition.

Reference Book:

1. Serop K. Steven, Manufacturing Processes for Engineering Materials, Prentice Hall of India, 2004.