Department of Mechanical Engineering

About the Department: The Mechanical Engineering Department seeks to combine excellence in education and research with service to Defence. The goal of our academic programmes in mechanical engineering is to provide students with a balance of intellectual and practical experiences that enable them to address a variety of Defence needs. The Department is one of the largest departments.

The Department is known for research and projects in fluid dynamics, heat transfer, finite element methods, vibrations, experimental stress analysis, vehicle dynamics and other areas. Experimental and computational facilities are being continuously upgraded. The Department has established, over the years, a close interaction with the DRDO laboratories and industry. It has carried out a large number of consultancy and sponsored research projects, which have been successfully completed. A number of sponsored research projects are ongoing.

The Department has carried out significant curriculum development work in Mechanical Engineering. Apart from the regular courses the department offers, on a continual basis, a wide variety of short-term intensive programmes for personnel from DRDO laboratories, Armed Forces and industrial establishments. User-oriented M. Tech programmes on Armament/Combat Vehicles and Marine Engineering has been formulated as per the needs of the Defence sector. The Programmes offers a wide choice of specializations, electives and research areas. The department has laboratories in Mechanical System Design and Analysis lab, Vibration lab, Fluid & Thermal Engg lab and Manufacturing and Precision Engg lab etc.

Vision of the Department:

"The Department endeavours to become Centre of Excellence in Armaments/Combat vehicles, Marine engineering, Mechanical Systems Design and Robotics"

Mission of the Department:

To impart advanced training, update knowledge, and develop skillset required for R&D, design, development, production, quality assurance, and inspection of efficient and economical equipment/systems of armament, combat vehicles, marine systems for DRDO and Defence Services, other industries and society in large.

Program Educational Objectives (PEO's):

PEO1: Provide basic and advanced technical knowledge to the students in the field of Armament and Combat Vehicles, Marine Engineering, Mechanical System Design and Robotics.
PEO2: Students should be capable to undertake R&D, inspection, testing and evaluation of equipment/systems of Combat vehicles, Armaments, Marine and Robotic systems and other industries.

Program Outcomes (POs)

PO1: An ability to independently carry out research /investigation and development work to solve practical problems
PO2: An ability 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 program

Program Specific Outcomes (PSOs)

PSO1: The specific outcome of the program is to provide human resources equipped with advanced applied knowledge in the field of armaments & combat vehicle technology, marine engineering and mechanical system design to fulfill the needs of DRDO, Army, Navy and Defence PSU's and other industries thereby making the country self-reliance.

PSO2: To be able to apply advanced engineering principles and concepts to design of equipment/systems of armament & combat vehicles, marine and other industries within realistic constraints.

PSO3: To be able to design and device new procedures to arrive at a solution for design or troubleshooting problems at the system/component level.

M. Tech. in Mechanical Engineering [Marine]

Brief Description: The aim of the programme is to impart advanced training and to update knowledge in the field of marine systems like gas turbine, engines, tribology, warship transmissions and nuclear engg etc, to engineering officers from Indian Navy, Coast Guard, DRDO scientists, DPSUs and GATE qualified students. At the end of the programme the officer/student should be able to undertake R&D work and evaluation of Marine Engineering Equipment systems.

Eligibility: Bachelor's Degree in Mechanical/Marine Engineering of a recognised Institute/University.

Organization: M. Tech Mechanical Engineering with specialisation Marine Engineering is a four-semester programme. In the first semester there are six courses. In second semester, there are six courses. In each of these semesters, there will be three tests and a final semester examination of every course. In 3rd and 4th semester dissertation work is to be completed. Half yearly evaluation of the project takes place at the end of the third semester. At the end of the final semester, student submits a thesis and makes a presentation about the project, which is evaluated by the Internal and External examiners.

Visits to various DRDO labs like NSTL, ARDE, GTRE, VRDE, Industry like MDL, GSL involved with Indian navy and naval technical facility are planned to enhance student's appreciation & understanding of the subject and provide them with opportunity to get hands on experience on various test equipment and procedures related to design, manufacturing and testing of Marine Engineering Equipments.

The details of the courses offered under the programme:

M. Tech. in Mechanical Engineering [Marine]

Semester I

Sl. No.	Course Code	Course	Credits		Total Credits (*)
			L	T/P	
1	ME 602	Advanced Mechanics of Materials	3	1	4
2	ME 603	Fluid Flow and Heat Transfer	3	1	4
3	ME 641	Warship Transmission & Tribology	3	1	4
4	ME 609	Mechanical Vibrations	3	1	4
5	ME 643	Ship Dynamics & Marine Systems	3	1	4
6	AM 607	Mathematics for Engineers	3	1	4
7	PGC-601	Research Methodology and IPR	2	0	2
		Total	**20**	**6**	**26**

Semester II

Sl. No.	Course Code	Course	Credits		Total Credits (*)
			L	T/P	
1	ME 607	Computational Fluid Dynamics	3	1	4
2	ME 644	Marine Diesel & Steam Engines	3	1	4
3	ME 645	Marine Gas Turbines	3	1	4
4	ME 646	Nuclear Reactor Engg.	3	1	4
5	--	Elective I	3	1	4

6	--	Elective II	3	1	4
7	PGC-602	Audit 1 and 2	2	0	0
		Total	**20**	**6**	**24**

Semester III

Sl. No.	Course Code	Course	Credits		Total Credits (*)
			L	T/P	
1	ME 651	M.Tech. Dissertation Phase I	14		14
		Total	**14**		**14**

Semester IV

Sl. No.	Course Code	Course	Credits		Total Credits (*)
			L	T/P	
1	ME 652	M.Tech. Dissertation Phase II	14		14
		Total	**14**		**14**

*** 1 credit in Theory/Tutorial means one contact hour per week and 1 credit in Practice/Project Thesis means two contact hours per week.**

List of Electives

Sl. No.	Course Code	Course Name
Elective I & II		
1.	ME 604	Advanced Materials and Processing
2.	ME 608	Finite Elements Methods
3.	ME 611	Design for Manufacturability
4.	ME 615	Trials & Evaluation of Weapon Systems
5.	ME 616	Thermal Management of Defence Equipment
6.	ME 617	Kinematics and Dynamics of Machinery
7.	ME 618	Composite Structures
8.	ME 619	Tribology for Design
9.	ME 627	Fatigue, Fracture and Failure Analysis
10.	ME 628	Design of Hydraulic and Pneumatic Systems
11.	ME 629	Design of Experiments
12.	ME 630	Design of Machinery
13.	ME 631	Product Design and Development
14.	ME 632	Design Optimization
15.	ME 633	Mechanical behavior of materials
16.	ME 634	Experimental Stress Analysis
17.	ME 635	CAD
18.	ME 636	MEMS: Design, Fabrication and Characterization
19.	ME 637	Design of Pressure Vessels
20.	ME 642	Automatic Control Systems
21.	ME 654	Convective Heat & Mass Transfer
22.	ME 655	Performance Testing and Instrumentation
23.	ME 657	Marine Hydrodynamics
24.	ME 658	Additive Manufacturing

25.	ME 659	Rapid Prototyping
26.	ME 660	Heat Exchanger Design
27.	AM 602	Mathematical Modeling & System Analysis
28.	AM 603	Adv Optimization Techniques
29.	AM 604	Advanced Statistical Techniques
30.	AM 623	Machine Learning
31.	AM 624	Advanced Numerical Methods
32.	TM 602	R&D Management
33.	TM 603	Project Management
34.	TM 604	Strategic Management
35.	TM 609	System Engineering
36.	MS 601	Introduction to Materials
37.	MS 607	Design of Materials
38.	MS 606	Advanced Physical and Mechanical Metallurgy
39.	MS 612	Non Destructive Evaluations
40.	MS 611	Advanced Functional Materials
41.	MS 613	Advanced Steel Technology
42.	AC 603	Thermodynamics and Combustion Process
43.	AP 610	Nanotechnology
44.	CE696A	Artificial Intelligence & DSS
45.	CE699	Internet of Things
46.		Open Electives from other departments

Notes:

1. Department has to decide which subjects should be offered as Elective I, II in the Semester II.
2. Practice school (Optional) of 4 weeks duration during Summer Vacation.

M. Tech. in Mechanical Engineering [Mechanical System Design]

Brief Description: M. Tech. in Mechanical Engineering (Mechanical System Design) plays a vital role in the field of Mechanical Engineering discipline from the fundamentals to applications in industrial/Defence practices. The importance of this program is vivid from understanding basics, design, development and implementation of mechanical system.

The objective of entire program is to impart knowledge to Engineers/ Scientists pertaining to Mechanical system design from the basics of engineering to final machine or equipment design ready to use in engineering system. This can be achieved by teaching a candidate different range of subjects for enhancing their analytical skills related to Machine design. Other objective of the program is to produce quality design engineers to cater to the needs of the relevant industry. The programme is conducted by well-versed faculty, invited experts from reputed institutions and industries.

Eligibility:

1. Bachelor's Degree in Mechanical/Production/Automobile/Mechatronics/Metallurgy and materials/Mining/Aerospace Engineering of a recognized Institute/University.
2. This programme is open for civilian GATE qualified candidates, DRDO Scientists/Officers and Officers from Tri-services. This programme is also open to foreign nationals from the countries approved by GOI.

Organization: M. Tech Mechanical Engineering with specialisation in Mechanical System Design is a four-semester programme. In the first semester, there are six courses. Second semester consists of six courses. In each of these semesters, there will be three tests and a final semester examination for every course. In third semester, M. Tech. (phase I) dissertation is there and in fourth semester, phase-II dissertation work is to be completed. Half yearly evaluation of the project takes place at the end of the third semester. At the end of the final semester, student submits a thesis and makes a presentation about the M. Tech. project, which is evaluated by the Internal and External examiners.
The details of the courses offered are:

The details of the courses offered under the programme:

M. Tech. in Mechanical Engineering [Mechanical System Design]

Semester I

Sl. No.	Course Code	Course	Credits		Total Credits (*)
			L	T/P	
1	ME 602	Advanced Mechanics of Materials	3	1	4
2	ME 603	Fluid Flow and Heat Transfer	3	1	4
3	ME 604	Advanced Materials and Processing	3	1	4
4	ME 609	Mechanical Vibrations	3	1	4
5	ME 618	Composite Structures	3	1	4
6	AM607	Mathematics for Engineers	3	1	4
7	PGC-601	Research Methodology and IPR	2	0	2
		Total	**20**	**6**	**26**

Semester II

Sl. No.	Course Code	Course	Credits		Total Credits (*)
			L	T/P	
1	ME 631	Product Design and Development	3	1	4
2	ME 630	Design of Machinery	3	1	4
3	ME 608	Finite Element Methods	3	1	4
4	ME 627	Fatigue, Fracture and Failure Analysis	3	1	4
5	--	Elective I	3	1	4
6	--	Elective II	3	1	4
7	PGC-602	Audit 1 and 2	2	0	0
		Total	**20**	**6**	**24**

Semester III

Sl. No.	Course Code	Course	Credits		Total Credits (*)
			L	T/P	
1	ME 651	M.Tech. Dissertation Phase I	14		14
		Total	**14**		**14**

Semester IV

Sl. No.	Course Code	Course	Credits		Total Credits (*)
			L	T/P	
1	ME 652	M.Tech. Dissertation Phase II	14		14
		Total	**14**		**14**

*** 1 credit in Theory/Tutorial means one contact hour per week and 1 credit in Practice/Project Thesis means two contact hours per week.**

List of Electives

Sr. No.	Course Code	Course Title
1	ME 607	Computational Fluid Dynamics
2	ME 611	Design for Manufacturability
3	ME 617	Kinematics and Dynamics of Machinery
4	ME 619	Tribology for Design
5	ME 628	Design of Hydraulic and Pneumatic Systems
6	ME 629	Design of Experiments
7	ME 632	Design Optimization
8	ME 633	Mechanical behavior of materials

9	ME 634	Experimental Stress Analysis
10	ME 635	CAD
11	ME 636	MEMS: Design, Fabrication and Characterization
12	ME 637	Design of Pressure Vessels
13	ME 654	Convective Heat & Mass Transfer
14	ME 658	Additive Manufacturing
15	ME 659	Rapid Prototyping
16	ME 660	Heat Exchanger Design
17	ME 662	CAM
18		Open Electives from other departments

Notes:

1. Department has to decide which subjects should be offered as Elective I, II in the Semester II.
2. Practice school (Optional) of 4 weeks duration during Summer Vacation.

M. Tech. in Mechanical Engineering [Armament and Combat Vehicles]

Brief Description: DRDO has been involved in the design and development of efficient and economical Combat Engineering & Armament Systems for Indian Armed Forces. The programme is designed to provide students with the principles of Combat Vehicle Technology and Armament Engineering. The programme pays special attention to:

- The study of advances in combat vehicle technology and armament engineering.
- Developing skills in the analysis and evaluation of new concepts against changes and developments in the threat.
- The user requirements needed to meet the threat and its implications.

Eligibility:

3. The eligibility for the postgraduate programme will be Bachelor's degree in **Mechanical/ Production/ Automobile/ Materials/ Metallurgy/ Mechatronics** Engineering disciplines from recognized university.

4. This programme is open for civilian GATE qualified candidates, DRDO Scientists/Officers and Officers from Tri-services. This programme is also open to foreign nationals from the countries approved by GOI.

Organization: M. Tech Mechanical Engineering with specialisation in Armament and Combact Vehicles is a four-semester programme. In the first semester there are six courses, in second semester, there are six courses. In each of these semesters, there will be three tests and a final semester examination for every course. In third semester M. Tech. (phase I) dissertation is there and in fourth semester, only dissertation work is to be completed. Half yearly evaluation of the project takes place at the end of the third semester. At the end of the final semester, student submits a thesis and makes a presentation about the M. Tech. project, which is evaluated by the Internal and External examiners.

The details of the courses offered under the programme:

M. Tech. in Mechanical Engineering [Armament and Combat Vehicles]

Semester I

Sl. No.	Course Code	Course	Credits		Total Credits (*)
			L	T/P	
1	ME 601	Armament & Combat vehicles-I	3	1	4
2	ME 602	Advanced Mechanics of Materials	3	1	4
3	ME 609	Mechanical Vibrations	3	1	4
4	ME 604	Advanced Materials and Processing	3	1	4
5	ME 605	Introduction to Combat Systems	3	1	4
6	AM 607	Mathematics for Engineers	3	1	4
7	PGC-601	Research Methodology and IPR	2	0	2
		Total	**20**	**6**	**26**

Semester II

Sl. No.	Course Code	Course	Credits		Total Credits (*)
			L	T/P	
1	ME 610	Armament & Combat Vehicles-II	3	1	4
2	ME 613	Armour Protection Systems	3	1	4
3	ME 660	Heat Exchanger Design	3	1	4
4	ME 661	Computational Fluid-Structure Interaction and its Applications	3	1	4
5	--	Elective I	3	1	4
6	--	Elective II	3	1	4
7	PGC-602	Audit 1 and 2	2	0	0
		Total	**20**	**6**	**24**

Semester III

Sl. No.	Course Code	Course	Credits		Total Credits (*)
			L	T/P	
1	ME 651	M.Tech. Dissertation Phase I	14		14
		Total	**14**		**14**

Semester IV

Sl. No.	Course Code	Course	Credits		Total Credits (*)
			L	T/P	
1	ME 652	M.Tech. Dissertation Phase II	28**		14
		Total	**28**		**14**

*** 1 credit in Theory/Tutorial means one contact hour per week and 1 credit in Practice/Project Thesis means two contact hours per week.**

List of Electives

S. No.	Course Code	Course Name
Elective I and II		
1.	ME 607	Computational Fluid Dynamics (CFD)
2.	ME 608	Finite Element Methods (FEM)
3.	ME 611	Design for Manufacturability
4.	ME 612	Modeling and Simulation of Military vehicles
5.	ME 654	Convective Heat and Mass Transfer
6.	ME 614	Unmanned Ground Vehicles
7.	ME 615	Trials & Evaluation of Weapon Systems

8.	ME 616	Thermal Management of Defence Equipment
9.	ME 617	Kinematics and Dynamics of Machinery
10.	ME 618	Composite Structures
11.	ME 619	Tribology for Design
12.	ME 620	High Energy Material Technology
13.	ME 621	Dynamics & Armament Mechanisms
14.	ME 622	Ballistics of bombs and projectiles
15.	ME 623	Design of ordnance, basic structure and super structure
16.	ME 624	Small arms and cannons
17.	ME 625	Combat Vehicle Technology
18.	ME 626	Vehicle Dynamics
19.	ME 627	Fatigue, Fracture and Failure Analysis
20.	ME 628	Design of Hydraulic and Pneumatic Systems
21.	ME 629	Design of Experiments
22.	ME 630	Design of Machinery
23.	ME 642	Automatic Control System
24.		Open Electives from other departments

Notes:

1. Department has to decide which subjects should be offered as Elective I, II in the Semester II.
2. Practice school (Optional) of 4 weeks duration during Summer Vacation.

Course Name- ***Armament and Combat Vehicles- I***
Course Code- ***ME 601***
Course Outcome:

CO1: Understand the basics of Vehicle Classification, Systems of Automotive Vehicles, Stability, Modularity, Transportability, Critical dimensions, Terramechanics, Power packs, Transmission, Steering and gear system, human response to vibrations of combat vehicles.

CO2: Understand the off road and amphibious vehicle design, Chassis design, different type of power packs, transmission system, quarter car and half car models. Evaluate Terramechanics behavior, relative performance of power packs, Hydrokinetic and Hydro static Drives. Apply constitutive equations for Terramechanics analysis and calculations of critical dimensions and evaluate engineering constants and analyze combat vehicle behavior at macro level.

CO3: Analyze the different components and their functions in connection with combat vehicle design and apply the understanding to the design of future systems

CO4: Understand and evaluate the requirement of different components as per futuristic combat vehicle design and proposing solution to the existing problems persisting in current inventory of combat vehicles.

Unit I: Introduction to Automotive systems: Vehicle Classification – On-Road (multi axle, trailer), Off Road (wheeled, tracked), Amphibious; Systems of Automotive Vehicles - Chassis / Body of vehicle; Power plant, Transmission; Additional design considerations: Vehicle stability, Modularity, Transportability to area of operation (by road, rail or by air), logistics for operation.

Unit II: Combat Vehicle design and Performance: Critical dimensions – NGP, MMP, Steerability ratio, Pitch ratio, Angle of approach, Angle of Departure, No. of Axles, No. of road wheels, Buoyancy for Amphibious vehicles; Terramechanics - soil strength, bearing capacity, Tractive effort, rolling resistance, draw bar pull and slip.

Unit III: Power packs for Combat Vehicles: Power plants - Reciprocating engines, Military Specials, Component technology advances, Space consideration (packaging subsystems), supercharging turbo charging; Cooling and air filtration systems; Engine management systems; Gas turbines (Rotary Engine) - Types for Combat vehicle use, Air handling, Fuel management system; Wankel Engines - Sealing and Lubrication systems; Non-conventional power plants - Types of electric traction motors, onboard power generation, storage and distribution system; Introduction to Fuel cells.

Unit IV: Transmission and Steering: Tractive requirement for wheeled and Tracked vehicles; Design of Clutches, Hydrokinetic and Hydro static Drives; Multi Axle all-wheel drive steering system for wheeled vehicles, Double differential steering for tracked vehicles, Skid steering for both wheeled and tracked vehicles; Electric / Hybrid transmission system; Brake system for combat vehicles.

Unit V: Running gear: Suspension system requirement - Quarter car and Half car analysis for displacement and force transmissibility; Ride - pitch and bounce behavior and optimization using damping; Types - Coil Spring, Torsion bar, Hydro Gas, Active, semi-active; Terrain characteristics. Human response to vibration, Suspension system requirements, Ride and handling of vehicles, Passive suspension system, hydro-gas suspension. Pitch and bounce behavior, Suspension system transmissibility, Suspension system optimization, Introduction to semi-active and active suspension.

Text Books/References:

1. Tank Technology (Vol I & II) by RM Ogorkiewicz – Jane's information Group, 1991 –
ISBN: 0710605951, 9780710605955.
2. TANKS: Main Battle and Light tanks (Brassey's Modern Military Equipment) , ISBN-13: 978-1857531688

3. Armoured Fighting Vehicles: Brassey's Modern Military Equipment, ISBN-13: 978-1857532036
4. Military Ballistics (Brassey's New Battlefield Weapons Systems & Technology Series into the 21st Century), ISBN-13: 978-18575308415. Theory of Ground Vehicles by J.Y.Wong – John Wiley & Sons, INC., 3rd Edition, ISBN: 0-471-35461-9

Course Name- ***Advanced Mechanics of Materials***
Course Code- ***ME 602***
Course Outcome:

CO1: Understand the fundamental concepts of stress and strain and the relationship between both through the strain-stress equations in order to solve problems for simple tri-dimensional elastic solids.

CO2: Determine Stress/strain invariants, principal strains and their directions.Analyze theories of failure to design components for safe operation.

CO3: Solve problems relating to non-uniform beams and thin-walled open section. Analyze the stresses in rotating discs, thick cylinder and bars subjected to torsion.

CO4: Develop constitutive relationships between stress and strain for linearly elastic solid and apply the concepts of energy methods in solving structural problems.

Unit I: Theory of Elasticity-Introduction, Stress. Differential equations of equilibrium, strain, compatibility conditions, plane problems of elasticity, stress strain relations, stress functions and applications in 2D problems. Pressurized cylinders & rotating disks, Governing equations, Stresses in thick walled cylinder under internal and external pressures. Introduction to experimental stress analysis.

Unit II: Energy Methods-Work done by forces and strain energy, reciprocal relations, Castigliano's theorems, Fictitious load method, statically indeterminate structures, theorem of virtual work, generalization of Castigliano's theorem.

Unit III: Asymmetrical Bending of beams-Bending of prismatic bars and unsymmetrical bending. Concept of shear centre in symmetric and un-symmetric bending, Plate bending, bending of curved beams.

Unit IV: Torsion of non-circular sections-Introduction, torsion of general prismatic solid section like circular, elliptical, rectangular, triangular shafts, membrane analogy, torsion of thin walled tubes, torsion of thin walled multiple cell closed sections.

Text Books/References:

1. Theory of Elasticity, 1970, Timoshenko SN & GoodierJN, McGraw Hill.
2. Advanced Mechanics of Materials, 2nd Ed., 1998 Cook RD & Yound WC, Prentice Hall.
3. Advanced Mechanics of Materials, 5th Ed., 1995 Boresi AP, Sidebottom OM, John Wiley.
4. Experimental Stress Analysis, 3rd Ed., 2005, Dally JW & Riley WF, College House Enterprises.

Course Name- ***Fluid Flow & Heat Transfer***
Course Code- ***ME 603***
Course Outcome:

CO1: Understand and review of basics of fluid mechanics.

CO2: Understand the basic governing equations of fluid flow and heat transfer, Application of dimensional analysis in fluid flow and heat transfer problems.

CO3: Application of governing equations in various process, Problem solving skills of fluid flow and heat transfer.

CO4: Understand the turbulent models for CFD, knowledge of compressible flow and heat transfer, Application of governing equations of fluid flow and heat transfer.

Unit I: Review of concepts in kinematics of Fluid Motion, Vorticity, Circulation, Velocity potential and Stream function. Reynolds transport theorem, Governing equations in integral form, Momentum Theorem, Applications in Propulsion, Energy equations, Applications.
Unit II: Potential flows, Applications, Integration of Euler's equations of motion. Governing Equations of fluid flow in differential form, Navier-Stokes Equations and exact solutions, Energy Equation and solution of fluid flow with thermal effects.
Unit III: Dimensional Analysis. Prandtl's Boundary Layer equations, Laminar Boundary Layer over a Flat Plate, Blausius solution. Turbulent flows in two-dimensional channels and pipes, Velocity field, Smooth and Rough pipes, Drag reduction in pipes, Turbulent Boundary Layer over a Flat Plate, logarithmic Law of wall, Effect of Pressure gradient, Boundary Layer control.
Unit IV: Speed of sound and Mach number, Basic equations for one dimensional flows, Isentropic relations, Normal-shock wave, Rankine-Hugoniot relations, Fanno and Rayleigh curve, Mach waves, Oblique shock wave, Prandtl-Meyer expansion waves, Quasi-one dimensional flows, Compressible viscous flows, Compressible boundary layers.
Unit V: Introduction to Heat Transfer.

Practice:

- Steady State Determination of heat transfer temperature difference and surface heat transfer coefficient for a single tube in a transversely flowing air stream.
- Determination of the Relationship between Nusselt and Reynolds Number for the forward stagnation point on a cylinder in cross flow using the Direct Heat Transfer Cylinder.
- Determination of the heat transfer rate and the exchanger effectiveness.
- Measure the distribution of Total pressure and Static Pressure along the duct and to compare these with the predictions of Bernoulli's equation
- Measure the Temperature of Furnace by using the thermal Image Camera.

Text books:

1. "Introduction to Fluid Mechanics**"** by R.W. Fox and A.T. McDonald, McGraw Hill
2. "Fluid Mechanics" by Kundu & Cohen, Elsevier Publications
3. Heat Transfer by J P Holman and Souvik Bhattacharyya (10th Edition, McGraw Hill Education)

References:

1. Viscous Fluid Flow, 2005, F. M. White, McGraw-Hill.
2. Boundary Layer Theory, 8th ed, 2000, Herrmann Schlichting, Springer

Course Name- ***Advanced Materials and Processing***
Course Code- ***ME 604***

Course Outcome:

CO1: Understand the advanced materials and its manufacturing processes for engineering applications and analyze Piezoelectric materials (PZT).

CO2: Analyze the Shape memory alloys (SMA), Electro rheological (ER) and magneto-rheological (MR) materials.

CO3: Understand the Composite materials and Micro-electro-mechanical (MEMS) systems.

CO4: Understand the Powder metallurgy and Advanced Material processing techniques.

Unit I: Introduction of advanced materials and its manufacturing processes for engineering applications. Piezoelectric materials (PZT)- Piezoelectric effect, Di-electric hysterisis, piezoelectric constants, piezoelectric charge constants, dynamic behaviour of PZT transducers, piezoelectric materials and manufacturing techniques (stability, poling and depolarisation).
Unit II: Shape memory alloys (SMA)- Shape memory effect and the metallurgical phenomenon of SMA, Temperature assisted shape memory effect, Visco-elastic behaviour, magnetic shape memory effect. Various shape memory alloys. Manufacturing technology of SMAs.
Unit III: Electro rheological (ER) and magneto-rheological (MR) materials- Characteristics of ER and EM fluids. ER and EM materials.

Unit IV: Composite materials- Design and manufacturing of polymer matrix, metal matrix and ceramic matrix composites. Various forms and type of reinforcements, fillers and additives. Design of composites for structural, wear resistance and high temperature applications.

Unit V: Micro-electro-mechanical (MEMS) systems- Introduction, characteristics of silicon wafers and other materials for MEMS applications. Various manufacturing techniques of MEMS components Materials for high temperature applications - Ni-Cr alloys, ODS materials, Ni base and Co based super alloys, carbon-carbon composites.

Unit VI:Powder metallurgy- Introduction and feature of powder metallurgy processes. Advanced solidification techniques: directional solidification, single crystal growth and levitation melting.

Unit VII: Advanced Material processing techniques- Thermal spraying, Ion beam machining, Laser and Electron beam processing, Friction Stir Welding, Special alloys machining, Superplastic forming, Flow forming, Explosive forming, Thin films and their deposition, Diamond coating techniques-tribological applications, Diffusion bond coating of high temperature materials.

Text Books/References:

1. Gandhi, M.V. and Thompson, B.S., Smart materials and Structures, Chapman and Hall, 1992.
2. Otsuka, K. and Wayman, C. M., Shape memory materials, C.U.P, 1998
3. Taylor, W., Pizoelectricity, George Gorden and Breach Sc. Pub., 1985
4. Mallick, P.K., Fiber Reinforced Composites Materials, Manufacturing and Design Marcel Dekker Inc, New York, 1993.
5. William D Callister: Materials Science and Engineering: An Introduction, 6th Edition, Wiley Publication.
6. S. Kalpakjian and S. Schmid: Manufacturing Engineering and Technology, 4th Edition, Pearson Education.
7. M. P. Grover: Fundamentals of Modern Manufacturing: Materials, Processes & Systems , Prentice Hall.

Course Name- **Introduction to Combat Systems**

Course Code- **ME 605**

Course Outcome:

CO1: Understand the basics of threat spectrum depending upon types of conflicts, types of conventional threats, close combat and peace keeping missions.

CO2: Understand battle field environment in reference to firepower mobility and protection, Command-Control-Communication-Computer-Intelligence (C4I) - Network Centric Warfare - Battlefield Management System. Evaluate battle field environment and apply constitutive equations for firepower and protection analysis and calculations related to C4I and analyze the combat vehicle behavior at macro level.

CO3: Analyze different types of combat vehicle configurations and their role in connection with the battlefield requirements, man machine interface and apply the understanding to the design of future combat systems.

CO4: Understand and evaluate the requirement of maintainability of a combat system and Combat Vehicle Evaluation Techniques with different types of trials required for futuristic combat vehicle design and finding solution to the existing problems in current inventory of combat vehicles.

Unit I: Threat Spectrum - Types of Conflicts - Low level, Medium level, Heavy conflicts - Combat Vehicle during World Wars I & II - Post world wars Combat Vehicles.
Conventional threats - Tank threat, Mine threat, Missile threat; Non-conventional threats - Ariel threat - Aircrafts, Helicopters, Drones - Precision munitions delivered from various platforms - Nuclear threat - Conflicts in builtup areas - Close combat - peace keeping missions.

Unit II: Battle Field Environment - Firepower - Non lethal, low calibre, Heavy calibre (tank / Arty), Cannon launched Missiles; Mobility - Tactical, Strategic, Battle field Mobility - weight, transportability, logistics; Protection - Small arms, Splinters, KE attack, CE Attack, Passive and Active, camouflage and stealth; Command-Control-Communication-Computer-Intelligence (C4I) - Network Centric Warfare - Battlefield Management System - Situational awareness through sensors.

Unit III: Vehicle Configuration - On Road and Off Road vehicles; Soft skinned - logistics, strategic transport (special railway wagons and multi-axle road trailers), Medium Armoured (both wheeled and Tracked) - Infantry Combat Vehicles (ICV), Missile / Mortar Carrier Vehicle,

Artillery Vehicles, Armoured Repair and Recovery Vehicle (ARRV), Bridge Layer, Main Battle Tank (MBT).
Unit IV: Man Machine Interface - Human System Integration - Ergonomics - Environmental Control System - Packaging of systems.
Unit V: Maintainability - Design for maintenance - Maintenance Repair and Overhaul (MRO) - Modularity in design - Adaptability to different missions, Line Replaceable Units.
Unit VI: Combat Vehicle Evaluation Techniques - Automotive trials - Specialized test track for automotive trials; Weapon Trials - Special equipment for proving weapon, proving Ammunition and Proving Combat system as a whole; Different types of Trials - Development trials, User trials, Usage trials, Deployment trials.

Text Books/References:
1) Fighting vehicle, TW Terry, Brassey's, 1991
2) The Greenhill Armoured Fighting Vehicles Data Book - Ian Hogg – Greenhill books - ISBN: 1853673919, 978-1853673917
3) The Encyclopedias of Tanks and Armored Fighting Vehicles – Chris Foss, Will Fowler – Thunder Bay Press (CA) – ISBN: 1571458069, 978-1571458063
4) Tanks inside Out – Michael E. Haskew – ISBN: 1607101106, 978-1607101109 Modern

Tanks & Armoured Fighting Vehicles by Simon Dunstan – The Crowood Press, 2005

ISBN:1840371900, 9781840371901.

Course Name- ***Computational Fluid Dynamics (CFD)***
Course Code- ***ME 607***
Course Outcome:

CO1: Understand and review of basics of fluid mechanics, turbulence models etc
CO2: Understand the basic governing equations of fluid flow and heat transfer.
CO3: Understand Finite Difference, Finite element and Finite Volume methods.
CO4: Understand Grid generation, errors and uncertainties, Practical's on CFD software (FLUENT) for better understanding

Unit I: Basic of Computational Fluid Dynamics. Governing Equations of fluid mechanics and heat transfer: Continuity, momentum and energy equations, physical boundary conditions, basic aspects of Discretization.
Unit II: Finite Difference, Finite element and Finite Volume formulation of steady/transient one-dimensional conduction equation, Finite Volume formulation of steady one-dimensional convection and diffusion problems: CDS, Upwinding scheme, hybrid scheme, unsteady problems: explicit scheme and Implicit scheme.
Unit III: Solution algorithms for pressure-velocity coupling in steady and unsteady flows. Discretization equations for two dimensional convection and diffusion. Unsteady heat conduction.
Unit IV: Numerical methods for the Navier-Stokes equation. Turbulence, Turbulence models: mixing length model, one equation model, Two equation (k-epsilon) models, LES, DNS.
Unit V: Grid generation, errors and uncertainties, Practical's on CFD software (FLUENT).

Practice in Ansys Workbench:

1. Turbulent Flow in a 2D elbow. (use water)
2. Laminar Flow in a 2D Pipe. (use water)
3. Flow over an Airfoil. (use air)
4. Laminar flow over a flat plate.
5. Flow through a pipe bend
6. Flow in multichannel

Text books:

1. An introduction to Computational Fluid Dynamics, 2nd edition, 2007, HK Versteeg & W Malalasekera, Pearson Education.
2. Computational Fluid Dynamics & Heat Transfer, 1984, Anderson, Dale A, John C Tanehill and Richard H Pletcher, McGraw Hill.

References:

1. Introduction to Computational Fluid Dynamics, 2005, Anil W Date, Cambridge University Press, NY, USA.
2. Numerical Heat Transfer and Fluid Flow, 1980, Patankar SV, Hemisphere, New York.

Course Name- ***Finite Element Methods***
Course Code- ***ME 608***

Course Outcome:

CO1: Understand the Prerequisites to Finite Element Methods, analyze the 1-D structural problems related to FEM and Introduction to Finite Elements in Engineering.

CO2: Analyze the 1-D structural problems including Analysis of Trusses and beams. Develop the understanding of 2D stress analysis using CST.

CO3: Analyze the Scalar field problems including 1-D and 2-D heat conduction problems. Analyze the 3-D problems using Tetrahedron element - Jacobian matrix - Stiffness matrix.

CO4: Understand the FEM through Case Studies including Modeling & Simulation of structural and non-structural problems using ANSYS, ABAQUS manuals.

Unit I: Prerequisites to FEM-Application of FEM, Strain- displacement relations, Stress-strain relations, Differential equations of equilibrium, Co-ordinates, basic element shapes, interpolation function, Minimum potential energy. Properties of stiffness matrix, treatment of boundary conditions, solution of system of equations, shape functions and characteristics.

Unit II: 1-D structural problems-***Analysis of axial bar element*** - stiffness matrix, load vector, temperature effects, Quadratic shape function. ***Analysis of Trusses***- Plane Truss elements, Transformation matrix, stiffness matrix, load vector Analysis of Beams - Hermite shape functions – beam stiffness matrix - Load vector - Problems

Unit III: 2-D stress analysis using CST-Plane stress, Plane strain, Force terms, Stiffness matrix and load vector, boundary conditions. Axisymmetric body subjected to axisymmetric loading-Numerical problems, Isoparametric element - quadrilateral element, linear shape functions.

Unit IV: Scalar field problems-1-D Heat conduction through composite walls, fins of uniform cross section, 2-D heat conduction problems, Torsional problems.

Unit V: Dynamic considerations-Dynamic equations - consistent mass matrix – Eigen values, Eigen vector, natural frequencies - mode shapes - modal analysis.**3-D problems-**Tetrahedron element - Jacobian matrix - Stiffness matrix, CAD softwares and its applications, Brief description to analysis of Plates & Shells.

Practice:

(i) Stress Analysis of Plate With Cut-outs using ANSYS/ABAQUS Software
(ii) Modal Analysis Of Cantilever Beam using ANSYS/ABAQUS Software
(iii) Case Studies etc.

Text Books/References:

1. Introduction to Finite Elements in Engineering, Tirupathi R.Chandrupatla and Ashok D. Belagundu, Pearson Education (Singapore) Pte Ltd, 2006.
2. An Introduction to Finite Element Methods, J.N. Reddy, Tata Mc Graw Hill, 2008.
3. A First Course in the Finite Element Method by Daryl L. Logan.
4. Concepts and Applications of Finite Element Analysis, Robert Cook, Wiley India, Pvt., Ltd., 4th Edition-2007.
5. An Introduction to Finite Element Methods, J.N. Reddy, Tata Mc Graw Hill, 2008.

6. Finite Element Procedures, K.J. Bathe, PHI Learning, 2009.
7. The Finite Element Methods in Engineering / SS Rao / Pergamon.

Course Name- ***Mechanical Vibrations***
Course Code- ***ME 609***
Course Outcome:

CO1: Understand the basics of single degree of freedom (DOF) systems such as free and forced vibrations of damped and undamped systems, Simple harmonic excitation, steady state response, torsional vibrations.

CO2: Understand vibration of systems with 2-DOF such as free and forced vibration of spring-mass-damper systems, torsional vibrations, modal analysis of undamped and damped systems.

CO3: Analyze the vibration of multi-DOF and continuous systems including free and forced vibration of beams, flexibility and stiffness influence coefficients with understanding of numerical methods.

CO4: Understand the experimental methods in vibration analysis with case studies including vehicle dynamics, fluid-structure interaction problems, vibration of suspension bridges.

Unit I: Single Degree of Freedom Systems- Free and forced vibrations of damped and undamped systems; Simple harmonic excitation; steady state response; torsional vibrations.

Unit II: Vibration of Systems with Two Degrees of Freedom- Free and forced vibration of spring-mass-damper systems; torsional vibrations; modal analysis of undamped and damped systems; numerical methods: Matrix iteration, Holzer's method, Dunkerley's lower and Rayleigh's upper bound approximations; Dynamic vibration absorbers

Unit III: Vibration of Multi-degree of Freedom and Continuous Systems: Vibrating string; Longitudinal and torsional vibration of rods; Free and forced vibration of beams; Properties of vibrating systems: Flexibility and stiffness influence coefficients; Reciprocity theorem; Eigenvalue analysis; Orthogonality of eigenvectors; Modal matrix

Unit IV: Experimental methods in vibration analysis: Vibration instruments: exciters, transducers, analysers, measurement devices: vibrometers, velocity meters and accelerometers; Signal analysis techniques: time domain analysis, frequency domain analysis, amplitude and power spectra, coherence, auto and cross correlations, amplitude and frequency modulations; Tests for free and forced vibrations

Unit V: Case studies (A) -Vehicle dynamics: introduction to nonlinear and random vibrations, vehicle subjected to random vibrations (for example an uneven road); Fluid-structure interaction problems: vibration of suspension bridges. **Case studies (B) -** Introduction to nonlinear and random vibrations, structures subjected to random vibrations, Noise control and acoustics.

Practice:

1. Undamped free vibration test of Single degree of freedom on Vibration Fundamental Trainer (VFT)
2. Frequency response function of spring mass damper system for various damping mediums: air, water, and oil.
3. Beam lateral experiment.

Text Books:

1. Introductory Course on Theory and Practice of Mechanical Vibrations, J.S.Rao, K.Gupta, Revised second edition, New Age International Publishers
2. Theory of Vibration with Applications, William T. Thomson, Marie Dillon Dahleh, Pearson Low Price Edition.
3. Mechanical Vibrations, J.B.K. Das & P.L.S.Murthy, Sapna book house.

Reference Books:

1. Principles and Techniques of Vibrations, Leonard Meirovich, Prentice Hall Inc.
2. Engineering Vibration, DJ Inman, Prentice Hall International Inc.

3. Mechanical Vibration and Shock Measurements, J.T.Broch, Bruel and Kjae Publication.
4. Applications of Random Vibrations, N. C. Nigam, S. Narayanan, Narosa Publishers.

Course Name- ***Armament and Combat Vehicles II***
Course Code- ***ME 610***
Course Outcome:

CO1: Understand the basics of Armament Systems and ballistics, learn fundamentals of Weapon System and its classification, Principles and Factors affecting Design of Weapon, Weapon mount, Projectile and Turret, Ammunition & Missile Feed Systems, Extraction and Ejection Systems. Learn fundamentals of Gun and Rocket; Internal, Intermediate, External and Terminal ballistics and actors affecting performance of the weapon.

CO2: Understand about Gun and Rocket; Internal, Intermediate, External and Terminal ballistics and factors affecting performance of the weapon. Learn and understand about Warhead Mechanisms, Ammunition and Design aspects of various types of fuzes. Apply constitutive equations for Internal, Intermediate, External and Terminal ballistics and evaluate engineering constants and analyze combat vehicle behavior at macro level.

CO3: Analyze the different components and their functions in connection with Weapon Sighting and Fire control system. Understand and analyze types of Sighting Systems and their roles along with fire control systems. Emerging trends and feature of sighting and fire control system.

CO4: Understand the requirement of different components as per futuristic combat vehicle design and proposing solution to the existing problems persisting in current inventory of combat vehicles.

Unit I:Armament Systems: Weapon System classification, Characteristics and Operating, Principles (Large caliber & Small caliber, Rockets, Missiles & Directed Energy Weapons (DEW)); Introduction to Turret and Weapon System (TWS), Principles and Factors affecting Design of Weapon, Weapon mount, Projectile and Turret; Automatic Fire - Blowback, Recoil System, Gas Operation systems and externally driven; Subsystems - Ammunition & Missile Feed Systems, Trigger and Firing Systems, Extraction and Ejection Systems, Locking, Mechanical Safety and Muzzle Attachments.

Unit II: Introduction to ballistics: Gun and Rocket; Internal, Intermediate, External and Terminal ballistics; Factors affecting performance of the weapon.

Unit III: Warhead Mechanisms: Configuration and classification of Warhead; Kill mechanisms – Kinetic Energy (long rod, fragmentation), Chemical Energy (Blast, Shaped Charge– HEAT, HESH, Explosive dynamics.); Explosives used in warheads.

Unit IV: Ammunition: Charge systems BL and QF. Primers and explosive trains; Design aspects of various types of fuzes.

Unit V: Introduction to Weapon Sighting system

Types of Sighting Systems and their roles, Building Blocks, Night Vision Systems, Infrared Imaging, Elements of thermal imaging systems, Day vision systems-Charged Coupled Devices (CCD) and CMOS Vision Systems, Elements of Day Vision Camera, Laser systems-Laser range finders, Laser Guidance & Designator, safety issues, Line of Sight Stabilization, Interfaces Types of Displays, Emerging trends and feature of sighting System.

Unit VI: Introduction to Fire Control System

Different Configurations of Fire Control systems, Building Blocks of IFCS, Features and salient Specifications, Gunner's Main Sight (GMS)-Elements of GMS, Configurations of GMS, Automatic target tracker, Commander's Sight- Salient Features and configuration, Panorama generation and Auto queuing, Ballistic computation, Gun Control system and its types.

Text Books/References:

1. "Handbook of Infantry Weapons", Part – 1, RMCS, UK, 1987
2. D Allsop, L Popelinsky et al, "Brassy's Essential Guide to Military Small Arms: Design Principles and Operating Methods", Brassy's, UK, 1997
3. "Engineering Design Handbook: Automatic Weapons", AMC Pamphlet No. 706 – 260,
4. US Army Material Command, Washington, 1970
5. Military Ballistics: A Basic Manual (Brassy's New Battlefield Weapon System and Technology Series) 1999, CL Farrar, DW Leeming, GM Moss, Brassey's (UK) Ltd.

6. Surveillance and Target Acquisition Systems: Brassey's Land Warfare, 1997, MA Richardson, IC Luckraft and RF Powell, London:Brassey's, ISBN 978-1857531374
7. Richard M Lloyd, "Conventional Warhead Systems Physics and Engineering Design", Vol. 179, Progresses in Astronautics and Aeronautics, 1998
8. Guided Weapons: Including Light, Unguided Anti-Tank Weapons, 3rd edition, 1998, RG Lee, TK Garland Collins, CA Sparkes and E Archer, London: Brassey's, ISBN 978-1857531527
9. Richard M Lloyd, "Conventional Warhead Systems Physics and Engineering Design", Vol. 179, Progresses in Astronautics and Aeronautics, 1998
10. MYH Bangash, "Impact and Explosion Dynamics Analysis and Design", Blackwell Scientific Publications, 1993.

Course Name- ***Design for Manufacturability***
Course Code- ***ME 611***

Course Outcome:

CO1: Understand the Design for manufacture overview, GD&T, Processing techniques and limitations.

CO2: Understand the Design for Manufacturing (DFM) and Fundamental principles of DFM.

CO3: Understand the Design for Assembly (DFA) and Concurrent engineering approach.

CO4: Analyze the Design Evaluation Tools/Softwares.

Unit I: Manufacturing Considerations in Design- Design for manufacture, Tolerencing and tolerance analysis. Processing techniques and limitations for metals, polymers and ceramics. Influence of materials in processing and tooling on the design of components. Finishing, surface coatings and surface modifications of materials.

Unit II: Engineering Design- Design of cast, forged, sheet metal parts and welded constructions. Design for assembly and dismantling, modular constructions. Erection, operation, inspection and maintenance considerations, Ergonomics.

Unit III: Machining considerations- Design for accuracy, locating pins and registers, machining in assembly, adjustment. Backlash and clearance adjustment. Examples illustrating the various principles. Available design variants for some of the common basic functional requirements.

Text Books/References:

1. Ashby, M. F. "Materials Selection in Mechanical Design", Pergaman Press, 1992.
2. Bralla J., "Handbook of Product Design for Manufacture", McGraw Hill, 1988.
3. Levy S., and Dubois, L. H, "Plastics Production Design Engineering Handbook, Methuen Inc., 1985.
4. Dieter G E, Engineering Desing, McGraw-Hill, 1991.
5. Yotaro Hatamura, The Practice of Machine Design, Claredon Press Oxfor, 1999.
6. Ertas Atilia and Jones J C, The Engineering Design Process, John Wiley & Sons, 1996.
7. Waldron B M and Kenneth J W, Mechanical Design: Theory and Methodology, Spriinger, 1996.

Course Name- ***Modeling and Simulation of Military Vehicles***
Course Code- ***ME 612***

1. Introduction to Multi Body Dynamics.
2. Vehicle dynamics evaluation using commercial software
(i) LMS Virtual Lab (or)
(ii) ADAMS, ADAMS (ATV) (or)
(iii) Recurdyn

2(a). Modelling of Track
- Super Element Track Modelling
- Discrete track modelling

2(b). Modelling of tyre
2(c). Modelling of Terrain

- 3D Surface modelling
- Representation of soft terrains

2(d) Steering and motion controls

2(e) Co-simulation techniques

2(f) Modelling of contact elements
- Contact between track and terrain
- Contact between track and other turning gear elements
- Contact between tyre and terrain

3. Introduction to Modal Analysis
- Virtual Experimental Modal Analysis (VEMA) using.

4. Structural analysis of hull and chassis
- Flexi body MBD modelling

5. Prediction of vehicle performance characteristics using vehicle dynamics model –
- Ride evaluation
- Low speed, high speed handling
- Obstacle crossing
- Mobility evaluation

6. Introduction to CFD softwares.
- CFD analysis of hull/body for hydrodynamic performance of vehicles engaged in swimming, planning, steering and other manoeuvres.

7. Armour / Ballistics
- Introduction to softwares such as LS Dyna, Radios
- Prediction for survivability of blast load or incoming projectile; penetration, or elastic and plastic deformation.

8. Experimental testing of vehicle and systems for validation of simulation models.

Text Books/References:

1. Multibody Dynamics: Computational Methods & Applicatios, 2007, J.C.G.Orden, J.M.Goicolea & J.Cuadrado, Springer, ISBN 978-1402056833
2. Study of Vehicles Handling & Riding Characteristics by ADAMS Software, 2012, Wael-Al-Tabey, LAP Lambert Academics Publishing, ISBN 978-3848439423
3. Tyre and Vehicle Dynamics, 2nd edition, 2005, Hans B Pacejka, Butterworth Hienemann, ISBN 978-0750669184
4. Modal Analysis, Zhi-Fang Fu and Jimin He, 2001, Butterworth Hienemann, ISBN 978-0750650793
5. Motor Vehicle Structure: Concepts and Fundamentals, 2002, JC Brown, AJ Robertson and ST Serpento, SAE International, ISBN 978-076800909
6. Introduction to Hydrocodes, 2004, Jonas Zukas, Elsevier Science, ISBN 978-0080443485
7. LS-DYNA for Begineers, 2012, LAP Lambert Academics Publishing, ISBN 978-3846556771

Course Name- ***Armour Protection Systems***
Course Code- ***ME 613***
Course Outcome:

CO1: Understand the basics of different type of threats and structural design required for protection against these threats.

CO2: Understand different type of Armours, soft kill and hard kill techniques. Evaluate different Armour Testing methods, NATO targets and Ballistic testing of Armour.

CO3: Analyze different case studies related to Reactive protection, electric armour etc. Active protection system layout and integration to platform, Intercepting mechanism and apply the understanding to the design of future systems.

CO4: Understand and evaluate the requirement of different Detection signature management techniques for acoustic, thermal, EM emissions etc. and proposing solution to the existing problems persisting currently.

Unit-I: Type of Threats: Threats to Armoured vehicles and systems. Frontal, top, side and bottom attacks. Armoured distribution on a typist MBT, ICV, body Armour.
Unit II: Structural Design and Protection: Structural requirements of armoured and nonarmoured vehicles; Armour Failure modes against Kinetic Energy (KE); Chemical Energy (CE).
Unit-III: Types of Armour: Small Armour and Splinters; Passive Armour - Rolled Homogenous Armour Steels, Aluminium Armour, Ceramic / Composite armour, Laminated / Spaced Armour, Explosive Reactive Armour; Active Armour - Soft Kill techniques amd Hard Kill techniques.
Unit-IV: Armour Testing: NATO targets. Ballistic testing of Armour.
Unit-V: Case Studies: Reactive protection, explosive reactive Armour (ERA), Inert Reactive Armour (IRA), Electric Armour. Methods to detect ERA case studies. Active protection system, Layout and integration to platform, Sensors and control mechanism, Intercepting mechanism and case studies.
Unit-VI: Detection signature management: Signature Management for acoustic, Thermal, usual and EM emissions. Deceptions and decoys, Early warning systems, Camouflages and concealments.

Text Books/References:

1. Fighting vehicle, 1st edition, 1991, TW Terry, Jackson SR, Ryley CES and Wormell PJH, London: Brassey's
2. Jane's Armor and Artillery 2011-12, Christopher F Foss, IHS Janes, ISBN 0978-0710629609
3. Advances in Ceramic Armor II: Ceramic Engineering and Science Proceedings, 1st edition, 2006, Andrew Wereszczak, Edgar Lara Curzio and Lisa Prokurat Franks, Wiley, ISBN 0978-0470080573
4. Dynamic Behaviour of Materials, 1st edition, Marc Andrew Meyers, Wiley-Interscience, ISBN 0978-0471582625
5. Ballistic Impacts on Polymer Matrix Composites-Composite Armor: Personal Armor, 2011, R Zaera, Springer:Vienna, ISBN 0978-3709105221

Course Name- ***Unmanned Ground vehicles***
Course Code- ***ME 614***

Introduction to UGV, Classification of UGV, History /World Scan, Major Technologies Sub system of UGV, Mobile UGV Kinematics, Locomotion, Drive by wire technology, Planning & Navigation, Obstacle detection & warning system, Power supply system, Perception System, Payloads, Vehicle Platforms, Automatic Transmission, Controllers Tele operation, Sensors & Actuators, Allied Technology, Applications.

Text Books/References:

1. Autonomous Mobile Robots by Roland Siegwart, Illah R. Nour bakhsh, Davide Scaramuzza (Printice Hall)
2. Autonomous robots: From biological inspiration to implementation and control, By Bekey, G.A.
3. Intelligent unmanned ground vehicles- autonomous navigation research at carnegie mellon,By Hebert, M.H. Thorpe, C Stentz, A.
4. Robot technology fundamentals, by Keramas, J.G.
5. Principles of robot motion Theory algorithms and implementations by Choset, H. Lynch, K.M. Hutchinson, S. Kantor, G. Burgard, W. Kavraki, L.E. Thrun, S.

Course Name- ***Trials & Evaluation of Weapon Systems***
Course Code- ***ME 615***

Unit I: Weapon system requirements. Weapon performance characterization, firing environment and ambient conditions. Factors affecting accuracy and consistency. Statistical methods. Mean and standard deviation, Error estimation due to normal distribution, Probable Errors, test of hypothesis, Design of experiment. Acceptance testing.
Unit II: Static test procedures, Shock and vibration tests, Accelarated environmental tests. Closed vessel test. Conditioning chambers. Test methods for evaluation of safety. Static trials of warheads.
Unit III: Dynamic trials. Range and its layout, Safety distances and surface danger zones. Measurement. Instruments: Pressure, MV, Trajectory, Atmosphere data, High speed videography and motion picture analysis.

Inbore pressure measurement. Telemetry and Data Acquisition. Post trial Analysis. Range and Accuracy Trial. Functioning Trial. Recovery trial and inspection.

Text Books/References:

1. Fighting vehicle, 1st edition, 1991, TW Terry, Jackson SR, Ryley CES and Wormell PJH, London: Brassey's
2. Surveillance and Target Acquisition Systems: Brassey's Land Warfare, 1997, MA Richardson, IC Luckraft and RF Powell, London:Brassey's, ISBN 978-1857531374
3. Statistical Methods, 2nd edition, 2003, Rudolph Freund and WJ Wilson, Academic Press Inc, ISBN 978-0122676512
4. Guided Weapons: Including Light, Unguided Anti-Tank Weapons, 3rd edition, 1998, RG Lee, TK Garland Collins, CA Sparkes and E Archer, London:Brassey's, ISBN 978-1857531527
5. Dynamic Systems: Modelling and Analysis, 1996, Ramin Esfandairi and Hung V Vu, Mc Graw Hill, ISBN 978-0072966619
6. Sensors: Advancements in Modelling, Design Issus, Fabrication and Practical Applications, 2008, Yueh-Min Ray Huang, Springer, ISBN 978-3540690306

Course Name- ***Thermal Management of Defence Equipment***
Course Code- ***ME 616***

Course Outcome:

CO1: Understanding of Heat transfer fundamentals and heat generating electronic equipment

CO2: Understanding of methods used for thermal management of electronic equipment

CO3: Understanding of the basics aspects of compactness, scaling laws of heat exchanger, various types of heat exchanger. Apply thermal design concepts to Industrial compact heat exchangers using LMTD Method

Syllabus Details	Outcome
Unit I & II	CO1
Unit III	CO2
Unit IV	CO3

Unit I: Heat-transfer fundamentals: conduction, convection, radiation, phase change, and heat transfer across solid interfaces.
Unit II: Heat-generating electronic equipment: ICs, power converters, circuit cards and electrical connectors.
Unit III: Thermal management equipment: heat sinks, interface materials, heat spreaders including liquid loops, and air movers. System design: system packaging architectures, facilities, system analysis. Advanced Topics: spray cooling, refrigeration
Unit IV: Introduction, Basic aspect of compactness, Scaling laws of heat exchangers, surface optimization, Industrial compact heat exchangers: Plate Fin heat exchangers, Tube Fin heat exchangers, Printed Circuit heat exchangers, Plate and Frame heat exchangers, Spiral heat exchangers, Plate and Shell heat exchangers. Surface comparisons, Size, shape and weight relationships, Surface types and correlations, Thermal Design-LMTD method.

Text Books/References:

1. Compact Heat Exchangers- Selection, Design and Operation, John E. Hesselgreaves, Gulf Professional Publishing, 2001.
2. Compact Heat Exchangers: Allan D. Kraus, R. K. Shah Hemisphere Pub. Corporation, 1990.
3. Heat Transfer -Thermal Management of Electronic Systems, Y Shabany, CRC Press.

Course Name- ***Kinematics and Dynamics of Machinery***
Course Code- ***ME 617***

Unit I: Machine kinematics- Overview, Degrees of freedom, Links and joints, Grashof condition, 4-bar linkage, slider-crank, and inverted slider crank.

UNIT II: Dynamics of rigid bodies in plane motion, Dynamic force analysis of machines:-Introduction to dynamics of machines, Equations of motion for a planar body, Equations for a mechanism Joint reactions, Different types of forces, Inverse dynamics- Determination of actuating forces, Forward dynamics – determination of accelerations given the actuating forces

UNIT III: Dynamics of rotating bodies: Unbalance in rotating machinery; Causes and effects of unbalance; Response of a simple rotor; Types of unbalance viz., static and dynamic; Balancing technique for achieving static balance; Balancing of rigid rotors; Two-plane method for balancing.

UNIT IV: Dynamics of Reciprocating Machines: Approximate acceleration analysis of an IC Engine mechanism, Equivalent Link model of a connecting rod, Estimation of Inertia forces in a crank-slider mechanism; Typical arrangements of multiple cylinders State of balance of typical multi-cylinder engines; The driving torque generated in an IC Engine due to gas forces; Issues in Matching of driving and load torques; Use of flywheels to smoothen the fluctuations in speed within a cycle.

Unit V: Programmable mechanisms- Introduction to industrial manipulators, Kinematic chains and classifications, Coordinate transformation, Forward and inverse kinematics

Text Books/References:

1. R. L. Norton, Design of Machinery: An Introduction to the Synthesis and Analysis of Mechanisms and Machines, McGraw-Hill, current edition.

Course Name- ***Composite Structures***
Course Code- ***ME 618***

Course Outcome:

CO1: Understand the basics of composite materials such as classification, characteristics, current and potential advantages and mechanical behavior of composites.

CO2: Understand the micro-mechanical behavior of lamina. Evaluate Elastic Moduli of lamina. Apply constitutive equations of composite materials and evaluate engineering constants and analyze mechanical behavior at macro level.

CO3: Analyze the macro-mechanical behavior of laminates and apply to the design of composite structures

CO4: Understand the fabrication methods, testing and characterization of composites

Unit I: Introduction composite materials-Classification and characteristics, mechanical behavior of composite materials, basic terminology, and manufacture of laminated fiber-reinforced composite materials, current and potential advantages of fiber –reinforced composite materials, applications of composite materials.

Unit II: Macro-mechanical behavior of lamina-Introduction, stress-strain relations for anisotropic materials, stiffnesses, compliances, and engineering constants for orthotropic materials, restrictions on engineering constants, stress train relation for plane stress in an orthotropic material, stress-train relations for lamina of arbitrary orientation, invariant properties of an orthotropic lamina, strengths of an orthographic lamina, biaxial strength criteria for an orthotropic lamina.

Unit III: Micro-mechanical behavior of lamina-Introduction, mechanics of materials approach to stiffness, elasticity approach to stiffness, comparison of approaches to stiffness, mechanics of materials approach to strength.

Unit IV: Macro-mechanical behavior of laminates-Introduction, Classical Lamination Theory, Special Cases Of Laminate Stiffness, Theoretical Versus Measured Stiffness, Strength Of Laminates, Inter-Laminar Stress.

Unit V: Introduction to design of composites structures-Introduction to structural design, material selection, configuration selection, laminate joints design requirements and design failure criteria, optimization concepts, design analysis philosophy for composite structures.

Unit VI: Fabrication methods of composites structures-Introduction to Various Fabrication Methods, VARTM And RFI Methods, Process Parameters In VARTM Method, Permeability Measurements, VARTM Process Model, Process Parameters of RFI Method Film Casting And Characteristics, Concepts Of VARTM and RFI Process Optimization.

Unit VII: Testing and characterisation of composites-Lamina strength characterization, tensile testing, compression testing, in-plane shear testing, short beam test, double cantilever beam test. Physical properties characteristion void content evaluation, fibre Volume Fraction Evaluation, DMA, DSC FOR Tg, Wet Properties Of Lamina, NDE Methods, Ultrasonic A-scan and CT-Scan Methods For Chracteristion Of Composites.

Text books:

1. Mechanics of composite materials, by Robert. M. Jones, second sedition, Taylor and Francis,1999.
2. Experimental characterization of advanced composites materials, third edition, Donald f Adams, Lief A. Carlsson and R. Byron pipes. CRC press.

Reference books:

1. Mechanics of fibrous composites by carl. T. Herakovich-john wiley and sons, 1997.55
2. Advanced composite materials, Lalit Gupta, Himalayan books. New delhi, 1998
3. Liquid moulding technologies, c d Rudd, a c long, k n Kendall and c g e Mangin, woodhead publishing limited, Cambridge England.
4. Process modeling in composites manufacturing, Suresh g advani, e. Murat sozer, Marcel Dekker, inc.

Course Name- ***Tribology for Design***
Course Code- ***ME 619***

Course Outcome:

CO1: Understand the basics of Tribology, Lubrication and its modes and additives, Bearings and its terminologies, Friction laws, classifications, theories and measurement.

CO2: Understand the Mechanics of Fluid Flow - Theory of hydrodynamic lubrication -Mechanism of pressure development in oil film, Two Dimensional Reynolds's Equation and its Limitations, Idealized Bearings, Infinitely Long Plane Fixed Sliders, Infinitely Long Plane Pivoted Sliders, Infinitely Long Journal Bearings, Infinitely Short Journal Bearings, Designing Journal Bearing- Sommerfeld number – Raimondi and Boyd method - Petroff's Solution - Parameters of bearing design - Unit pressure - Temperature rise - Length to diameter ratio - Radial clearance - Minimum oil-film thickness. Evaluate the load carrying capacity of the above mentioned bearings.

CO3: Understanding the basic of Hydrostatic and Squeeze Film Lubrication, Load carrying capacity and flow requirements, and its applications, Elasto-Hydrodynamic Lubrication principle and applications

CO4: Understand Friction and Wear-Friction - Laws of friction - Friction classification - Causes of Friction, Theories of Dry Friction, Friction Measurement, Stick-Slip Motion and Friction Instabilities, Wear - Wear classification - Wear between solids – Wear between solid and liquid - Analyse the effects of various Factors affecting wear – Measurement of wear, Theories of Wear, Approaches to Friction Control and Wear Prevention

Unit I: Introduction-Defining Tribology, Tribology in Design - Mechanical design of oil seals and gasket - Tribological design of oil seals and gasket, Tribology in Industry (Maintenance), Defining Lubrication, Basic Modes of Lubrication, Properties of Lubricants, Lubricant Additives, Defining Bearing, Terminology - Sliding contact bearings -Rolling contact bearings, Comparison between Sliding and Rolling Contact Bearings

Unit II: Friction and Wear-Friction - Laws of friction - Friction classification - Causes of Friction, Theories of Dry Friction, Friction Measurement, Stick-Slip Motion and Friction Instabilities, Wear - Wear classification - Wear between solids – Wear between solid and liquid - Factors affecting wear – Measurement of wear, Theories of Wear, Approaches to Friction Control and Wear Prevention

Unit III: Lubrication of Bearings-Mechanics of Fluid Flow - Theory of hydrodynamic lubrication -Mechanism of pressure development in oil film, Two Dimensional Reynolds's Equation and its Limitations, Idealized Bearings,

Infinitely Long Plane Fixed Sliders, Infinitely Long Plane Pivoted Sliders, Infinitely Long Journal Bearings, Infinitely Short Journal Bearings, Designing Journal Bearing- Sommerfeld number – Raimondi and Boyd method - Petroff's Solution - Parameters of bearing design - Unit pressure - Temperature rise - Length to diameter ratio - Radial clearance - Minimum oil-film thickness.

Unit IV: Hydrodynamic Thrust Bearing-Introduction - Flat plate thrust bearing - Tilting pad thrust bearing, Pressure Equation - Flat plate thrust bearing - Tilting pad thrust bearing, Load - Flat plate thrust bearing - Tilting pad thrust bearing, Center of Pressure - Flat plate thrust bearing - Tilting pad thrust bearing, Friction - Flat plate thrust bearing - Tilting pad thrust bearing

Unit V: Hydrostatic and Squeeze Film Lubrication-Hydrostatic Lubrication - Basic concept - Advantages and limitations - Viscous flow through rectangular slot – Load carrying capacity and flow requirement - Energy losses - Optimum design, Squeeze Film Lubrication - Basic concept - Squeeze action between circular and rectangular plates - Squeeze action under variable and alternating loads, Application to journal bearings, Piston Pin Lubrications.

Unit VI: Elasto-Hydrodynamic Lubrication-Principles and Applications, Pressure viscosity term in Reynolds's equation, Hertz's Theory, Ertel-Grubin equation, Lubrication of spheres, Gear teeth bearings, Rolling element bearings.

Unit VII: Gas (Air) Lubricated Bearings-Introduction, Merits, Demerits and Applications, Tilting pad bearings, Magnetic recording, discs with flying head, Hydrostatic bearings with air lubrication, Hydrodynamic bearings with air lubrication, Thrust bearings with air lubrication.

Unit VIII: Tribological Aspects of Rolling Motion-The mechanics of tyre-road interactions, Road grip and rolling resistance, Tribological aspects of wheel on rail contact. Finite Bearings-Hydrostatic bearings, Hydrodynamic bearings, Thrust oil bearings, Porous Bearings, Foil bearings, Heat in bearings.

Practice:

1. Surface roughness test,
2. Friction & Wear test on Pin on disc Machine
3. Case studies etc.

Text Books/References:

1. A. Harnoy , Bearing Design in Machinery, Marcel Dekker Inc, NewYork, 2003.
2. M.M.Khonsari & E.R.Booser, Applied Tribology, John Willey &Sons,New York, 2001.
3. E.P.Bowden and Tabor.D., Friction and Lubrication, Heinemann Educational Books Ltd., 1974.
4. A.Cameron, Basic Lubrication theory, Longman, U.K.., 1981.
5. M.J.Neale (Editor),Tribology Handbook , Newnes. Butter worth, Heinemann, U.K., 1995.

Course Name- ***High Energy Material Technology***
Course Code- ***ME 620***

Unit I: High Energy Materials: An overview, Current trends and Furture Directions, Characterization of High Energy Materials using Modern Instrumental Techniques.

Unit II: Solid Rocket Propellants: Introduction classification and specification of solid rocketpropellants, Ingredients, processing and performance of each class of propellants – Double base prolellants (DBP) – Extruded, Fuel Rich Propellants (FRP), NEPE Propellants, Insulatior-inhibitor-liner, X-ray radiography, Mechanical Characterization, Ignition system,

Ballistic Prediction, Instrumentation for Static firing of Rockets, Future directions in development of solid rocket propellants.

Unit III: Gun Propellants: Introduction and Gun propellants developed in India, Classification, ingredients and manufacturing of gun propellants (SBP, DBP, TBP, LOVA), Combustible Cartridge Case for gun ammunition, Closed Vessel evaluation and Performance prediction of gun propellants, Future trends.

Unit IV: High Explosives: Introduction and uses, Classification and manufacture of high explosives, Theory of detonation and blast, Plastic Bonded explosives, explosive compositions for Low Intensity Conflict (LIC), Expliosive Reactive Armour, Fuel – Air explosive, Thermobaric explosives compositon, Measurement and instrumentation.
Unit V: Pyrotechnics: Introduction, Classification and manufacture, Electo-explosive devices, Pyrotechnics smoke, Pyrotechic delays, Pyrotechnic Flares, Other devices, Instrumentation for performance measurement.
DETINICS, PBX & Insensitive Explosives.

Course Name- ***Dynamics & Armament Mechanisms***
Course Code- ***ME 621***

Unit I: Equation of motions, Frame of reference. Newtonia, Enterian, Langrangian, Hamiltonium formulation for motion dynamics. Euler angles and transformations. Translatory and Rotary motions. Constraint and unconstraint motion.
Unit II: Mechanisms: Linear, Rotary, Hydraulic and Pneumatic systems.
System dynamics for first and second order systems and response in time and frequency domain.
Unit III: Mechanisms of large Calibre Weapons: Balancing gear, Breech and Firing Mechanisms, Recoil Mechanisms, Laying Mechanisms, Ramming Mechanisms.
Unit IV: Small Arms Mechanisms: Introduction, Operating Mechanisms (Blow back, recoil and Gas operated), Feeding Mechanisms, Trigger and Firing Mechanisms, Ejection and Extraction Mechanisms.
Unit V: Fuze Mechanisms: Safety and Arming Mechanism, Spring Mass Mechanisms, Rotary Mechanisms, Clock work Mechanisms.
Launcher Platform Leveling, Laying, Sighting, Rocket Pinaka, Control Mechanisms.

Course Name- ***Ballistics of Bombs & Projectiles***
Course Code- ***ME 622***

Unit I: Basics of Ballistics of any projectile, Difference between precision, accuracy and CEP.
Unit II: Internal Ballistics (Guns): Burning of propellants, Vielle's mode and rate of burnings, form function, Resalls' Energy Equation. Internal ballistic solutions, Hunt hind Heydenreigh system. Lodue Method. Effect of vibrations in loading conditions, Similarity relations.
Unit III: External Ballistics (Guns): Aerodynamic force system. Normal equations. Siacci form of solutions, Numerical methods of trajectory computation, Meteorological corrections. Angular motion of the Centre of mass. Drift and deflection, Dispersion of fire.
Unit IV: External Ballistics of Rockets: Launch dynamics, plane trajectory, boost plane trajectory models, rocket accuracy (dispersion and stability), rocket-assisted projectiles.
Unit V: Bomb Ballistics: Aerodynamic forces and moments acting on a bomb, Drag co-efficient, Terminal velocity and Ballistic index, Trajectory of bombs, Simulated stores (similitude) and their trajectories, Bomb stability derivatives and analysis (in roll, pitch and yaw), wind tunnel testing, Bomb trajectory calculations with point mass and Six Degrees of Freedom Equations. Calculation of Moment of Inertia and Centre of Gravity of bombs.

Text Books/References:

1. Text Book of Ballistic & Gunnery, 1987,Vol I & II, HMSO Publication.
2. DE Carlucci & SS Jacobson Ballistics Theory and Design of Guns & Ammunition, 2007, CRC Press.
3. Military Ballistics: A Basic Manual (Brassey's New Battlefield Weapons Systems and Technology Series into 21st Century),1999, CL Farrar, DW Leeming, GM Moss, Brassey's (UK) Ltd.

Robert L McCoy Modern Exterior Ballistics, 2001, , Schiffer Publishing.

Course Name- ***Design of Ordnance, Basic and Super Structure***
Course Code- ***ME 623***

Unit I: Gun Barrel and Tube Launcher: Theory of failure, Gun Barrel Design, Material and Manufacturing by VAR, ESR, etc. Proof of ordnance, Design of Combustion Chambers. Gun tube acoustics.

Unit II: Breech Mechanism: Principles of operation and design of Muzzle Brakes, Fume Extractors and Firing Mechanisms
Unit III: Design of Structural Elements: Design of gun superstructure and basic structures. Curvilinear and soft recoil systems, articulation and suspension systems.

Text Books/References:

1. "Engineering Design Hand Book: Recoil Systems", AMC Pamphlets, Washington, 1978
2. Thomas J. Hayes, "Elements of ordnance", John Wiley, New York, 1952
3. "Engineering Design Hand Book: Recoil; Elevating and Traversing mechanisms; Cradles; Top carriage; Bottom Carriage and Muzzle Devices", AMC Pamphlets, Washington, 1968.

Course Name- ***Small Arms and Cannons***
Course Code- ***ME 624***

Unit I: Introduction: Classification, Characteristics and Operating Principles. Automatic Fire and Power Source. Principles and Factors affecting the choice and Design of Projectile and Weapon; Heating of Small Arms; Accuracy and Chance of Hit.
Unit II: Operating Principles: Analytical and Comparative Study of Blowback, Recoil and Gas Operation systems, and Externally Driven Weapon Systems.
Unit III: Subsystems: Feed Systems, Trigger and Firing Systems, Extraction and Ejection Systems, Locking and Mechanical Safety and Muzzle Attachments.
Manufacturing; Inspection; Life Estimation; Modern Trends; Typical Weapon Study: INSAS.

Text Books/References:

1. "Handbook of Infantry Weapons", Part – 1, RMCS, UK, 1987
2. D Allsop, L Popelinsky et al, "Brassy's Essential Guide to Military Small Arms: Design Principles and Operating Methods", Brassy's, UK, 1997
3. "Engineering Design Handbook: Automatic Weapons", AMC Pamphlet No. 706 – 260, US Army Material Command, Washington, 1970

Course Name- ***Combat Vehicle Technology***
Course Code- ***ME 625***

Unit I: AFV Characteristics : Concept of Tank warfare and design philosophies of AFVs, Development of Tanks, Design parameters of combat vehicles to include configuration, overall dimensions etc.
Unit II: Firepower : Characteristics, components, main gun and tank ammunition including ATGMs, secondary armament, Ranging & Sighting systems including NVD, GCE & ALG, Probability of Kill, Errors & Biases, Fire Control system.
Unit III: Mobility : Types, performance parameters, obstacle crossing ability, navigation – GPS & GLNS.
Unit IV: Protection : Types, Armour Protection, Active protection systems, Protection against NBC and Fire. Tank communication & IFF, Maintainability, Availability, Reliability and Ergonomics.
Unit V: Critical Dimensions and Design : Steerabilty ratio, Track Width, Pitch ratio, NGP , MMP, Angle of approach and Angle of departure, Pitch of tank, No of Road Wheels, Inter-relation between all dimensions and Design requirements.
Unit VI: Latest Trends, FMBT, FICV, Lt Tank, AFV Variants

Text Books/References:

1. Fighting vehicle, 1st edition, 1991, TW Terry, Jackson SR, Ryley CES and Wormell PJH, London: Brassey's
2. Ballistics: Theory and Design of Gun and Ammunition,2007, Donald E Carlucci and Sidney S Jacobson, CRC Press, ISBN 978-1420066180
3. Fundamentals of Vehicle Dynamics, Thomas D Gillespie, SAE International, ISBN 978-1560911999
4. Terramechanics and Off-road Vehicle Engineering: Terrain Behaviour, Off-Road Performance and Design, 2nd edition, J.Y.Wong, Butterworth Hienemann

5. Jane's Armor and Artillery 2011-12, Christopher F Foss, IHS Janes, ISBN 0978-0710629609
6. Dynamic Behaviour of Materials, 1st edition, Marc Andrew Meyers, Wiley-Interscience, ISBN 0978-0471582625
7. Projectile Impact: Modelling Techniques and Assessment of Target Material Performance, 2014, S Syngellakis, Wit Pr, ISBN 0978-1845648794
8. Protection Levels for Occupants of Logistic and Light Armored Vehicles, NATOSTANAG 4569

Course Name- ***Vehicle Dynamics***
Course Code- ***ME 626***

Unit I: Vehicle Ride : Human response to vibration, ISO standards, Response of idealized suspension systems to stop and sinusoidal disturbance in bounce and to wheel out of balance. Combined pitch and bounce motion, application to multi wheel station vehicles. Random ground input excitation, Use of sinusoidal transmissibility function to predict mean square motion of spring mass. Vehicle performance during cornering, Dynamic Vibration Absorber.
Unit II: Wheeled Vehicle : Vehicle transfer function. Kinematic behaviour of vehicles with rigid wheels and with compliant tyres, neutral steer point, static margin, over and under steer. Derivation of generalized equations of motion for a vehicle, stability derivative notation. Solution with two degree of freedom in the steady in yaw. Frequency response in yaw. Extension of two degree of freedom theory to include effects of traction and braking, self aligning torque, dual wheels and bogies. Development of equations of motion to include roll of sprung mass, Effect on steady state and frequency response.
Unit III: Tracked Vehicle Handling : Analysis of sprocket torques and speeds, required to skid steer a tracked vehicle. Modification of theory to allow for soil conditions and lateral Weight transfer. Application of theory of steering of articulated and half – track vehicles.
Unit IV: Terramechanics : Nature of soil vehicle interaction, Characteristics of soil and bearing capacity, Empirical approaches for prediction of vehicle mobility.

Text Books/References:

1. Fundamentals of Vehicle Dynamics, Thomas D Gillespie, SAE International, ISBN 978-1560911999
2. Auotmotive Handbook, 8th edition, Robert Bosch GmbH, Wiley Blackweel, ISBN 978-0837516865
3. A Textbook of Automobile Engineering-II, P.S.Gill, Katson Books, ISBN 978-9350140420
4. Automotive Transmission-Fundamentals, Selection, Design & Application, Giesbert Lechner and Herald Naunheimer, Springer, ISBN 978-3540659037
5. Theory of Ground Vehicles, 4th edition, J.Y.Wong, John Wiley & Sons, ISBN 978-0470170387
6. Shock Absorber Handbook, John.C.Dixion, SAE International, ISBN 978-0768018431
7. Car Suspenion and Handling, 4th edition, Goeffrey Howard, Donald Bastow and John Peter Whitehead, SAE International, ISBN 978-0768008722
8. Terramechanics and Off-road Vehicle Engineering: Terrain Behaviour, Off-Road Performance and Design, 2nd edition, J.Y.Wong, Butterworth Hienemann
9. Heavy-Duty Wheeled Vehicles: Design, Theory & Calculation, Boris Nikolaevich Belousov and Sergey.D.Popov, SAE International, ISBN 978-0768077230

Course Name- ***Fatigue, Fracture and Failure Analysis***
Course Code- ***ME 627***

Course Outcome:

CO1: Understand the fatigue failure of structures, physical aspects of fatigue, phase in fatigue life, fatigue fracture surfaces, statistical aspects of fatigue behaviors.

CO2: Understand fatigue failure Criteria such as Goodman, Gerber and Soderberg relations and diagram, **Apply** failure criteria and **evaluate** factor of safety to predict the safety of structure under operating loads.

Apply Miner's theory and other theories and **evaluate** life of structure under different loads for different no of cycles.

CO3: Understand fracture mechanics design concept**. Analyze** the fracture mechanics strength of cracked bodies. **Evaluate** stress intensity factors for typical geometries. **Analyze** effect of thickness on fracture toughness.

CO4: Understand the fatigue design and testing, safe life and fail-safe design philosophies, application to composite materials and structures. Evaluation of life of structures with damages.

Unit I: Fatigue of Structures-S.N. curves - Endurance limits - Effect of mean stress, Goodman, Gerber and Soderberg relations and diagrams - Notches and stress concentrations - Neuber's stress concentration factors - Plastic stress concentration factors - Notched S.N. curves.

Unit II: Statistical Aspects of Fatigue Behaviour-Low cycle and high cycle fatigue - Coffin - Manson's relation - Transition life - cyclic strain hardening and softening - Analysis of load histories - Cycle counting techniques - Cumulative damage - Miner's theory - Other theories.

Unit III: Physical Aspects of Fatigue-Phase in fatigue life - Crack initiation - Crack growth - Final Fracture - Dislocations - fatigue fracture surfaces.

Unit IV: Fracture Mechanics-Strength of cracked bodies - Potential energy and surface energy - Griffith's theory - Irwin - Orwin extension of Griffith's theory to ductile materials - stress analysis of cracked bodies - Effect of thickness on fracture toughness - stress intensity factors for typical geometries.

Unit V: Fatigue Design and Testing-Safe life and Fail-safe design philosophies - Importance of Fracture Mechanics in aerospace structures - Application to composite materials and structures.

Text Books/References:

1. Prashanth Kumar , Elements of fracture mechanics, Wheeter publication, 1999.
2. Barrois W, Ripely, E.L., Fatigue of aircraft structure, Pe/gamon press. Oxford, 1983.
3. Knott, J.F., Fundamentals of Fracture Mechanics, Buterworth & Co., Ltd., London, 1983.
4. David Broek, Elementary Engineering Fracture Mechanics, Kluwer Academic Publishers,1986.

Course Name- *Design of Hydraulic and Pneumatic Systems*
Course Code- *ME 628*

Unit I: Hydraulic System & Components-Sources of Hydraulic Power: Pumping theory – Pump classification – Gear pump, Vane Pump, piston pump, construction and working of pumps – pump performance – Variable displacement pumps. Fluid Power Actuators: Linear hydraulic actuators – Types of hydraulic cylinders – Single acting, Double acting special cylinders like tanden, Rodless, Telescopic, Cushioning mechanism, Construction of double acting cylinder, Rotary actuators – Fluid motors, Gear, Vane and Piston motors

Unit II: Design of Hydraulic Circuits-Construction of Control Components : Director control valve – 3/2 way valve – 4/2 way valve – Shuttle valve – check valve – pressure control valve – pressure reducing valve, sequence valve, Flow control valve – Fixed and adjustable, electrical control solenoid valves, Relays, ladder diagram. Accumulators and Intensifiers: Types of accumulators – Accumulators circuits, sizing of accumulators, intensifier – Applications of Intensifier – Intensifier circuit.

Unit III: Pneumatic Systems and Components-Pneumatic Components: Properties of air – Compressors – Filter, Regulator, and Lubricator Unit – Air control valves, Quick exhaust valves, and pneumatic actuators. Fluid Power Circuit Design, Speed control circuits, synchronizing circuit, Penumo hydraulic circuit, Sequential circuit design for simple applications using cascade method.

Unit IV:Design of Pneumatic Circuits-Servo systems – Hydro Mechanical servo systems, Electro hydraulic servo systems and proportional valves. Fluidics – Introduction to fluidic devices, simple circuits, Introduction to Electro Hydraulic Pneumatic logic circuits, ladder diagrams, PLC applications in fluid power control. Fluid power circuits; failure and troubleshooting.

Text Books:

1. Anthony Esposito, Fluid Power with Applications, Pearson Education 2000.
2. Majumdar S.R., Oil Hydraulics, Tata McGraw-Hill, 2000.
3. Johnson, James L., Introduction to Fluid Power, Delmar Publishers, 2003

Reference Books:

4. Majumdar S.R., Pneumatic systems – Principles and maintenance, Tata McGraw Hill, 1995
5. Harry L. Stevart D.B, Practical guide to fluid power, Taraoeala sons and Port Ltd. Broadey, 1976.
6. Michael J, Prinches and Ashby J. G, Power Hydraulics, Prentice Hall, 1989.
7. Dudelyt, A. Pease and John T. Pippenger, Basic Fluid Power, Prentice Hall, 1987.

Course Name- *Design of Experiments*
Course Code- *ME 629*

Unit I: Overview and Basic Principles, Simple Designs and Analysis of Variance,

Unit II: Block Designs, Latin Squares and Related Designs, Full Factorial Designs, 2-level Full Factorial and Fractional Factorial Designs.

Unit III: Response surface methods and designs, Designs with Random Factors, Nested Designs, and split-plot Designs.

Text Books/References:

1. Clewer, A.G. and D.H. Scarisbrick. 2001. Practical Statistics and Experimental Design for Plant and Crop Science. John Wiley and Sons, LTD. New York Morris, T.R. 1999.
2. Experimental Design and Analysis in Animal Sciences. CABI Publishing, New York

Course Name- *Design of Machinery*
Course Code- *ME 630*

Course Outcome:

CO1: Determine the kinematic chain and mobility, and perform the kinematic analysis of a given mechanism.

CO2: Identify the basic relations between distance, time, velocity, and acceleration and apply the fundamental principles of statics and dynamics to machinery

CO3: Understand and avoid/suppress certain common dynamical problems a machine may undergo and Apply vector mechanics as a tool for solving kinematic problems

CO4: Understand the fundamentals of machine design for desired kinematic or dynamic performance and use graphical and analytic methods to study the motion of a planar mechanism.

Unit I: Introduction- Classification of mechanisms – Basic kinematic concepts and definitions – Degree of freedom, Mobility – Kutzbach criterion, Gruebler‟s criterion – Grashof‟s Law – Kinematic inversions of four-bar chain and slider crank chains – Limit positions – Mechanical advantage – Transmission Angle – Description of some common mechanisms – Quick return mechanisms, Straight line generators, Universal Joint – rocker mechanisms.

Unit II: Kinematics of mechanisms/machineries- Displacement, velocity and acceleration analysis of simple mechanisms – Graphical method– Velocity and acceleration polygons – Velocity analysis using instantaneous centres – kinematic analysis of simple mechanisms – Coincident points – Coriolis component of Acceleration – Introduction to linkage synthesis problem.

Unit III: Dynamics of mechanisms/machineries-Dynamics Fundamentals, Dynamic Force Analysis, Balancing, Engine Dynamics, Multi cylinder Engines.

Unit IV: Kinematic and dynamic analysis of machine components- Classification of cams and followers – Terminology and definitions – Displacement diagrams –Uniform velocity, parabolic, simple harmonic and

cycloidal motions – Derivatives of follower motions – Layout of plate cam profiles – Specified contour cams – Circular arc and tangent cams – Pressure angle and undercutting – sizing of cams.

Law of toothed gearing – Involutes and cycloidal tooth profiles –Spur Gear terminology and definitions –Gear tooth action – contact ratio – Interference and undercutting. Helical, Bevel, Worm, Rack and Pinion gears [Basics only]. Gear trains – Speed ratio, train value – Parallel axis gear trains – Epicyclic Gear Trains.

Case Studies on design and development of models

Text Books/References:

1. R L Norton, Design of Machineries, 5th Edition, McGraw Hill Publishers.
2. Uicker, J.J., Pennock G.R and Shigley, J.E., Theory of Machines and Mechanisms, 3rd Edition, Oxford University Press, 2009.
3. Rattan, S.S, Theory of Machines, 3rd Edition, Tata McGraw-Hill, 2009.
4. Thomas Bevan, Theory of Machines, 3rd Edition, CBS Publishers and Distributors, 2005.
5. Cleghorn. W. L, Mechanisms of Machines, Oxford University Press, 2005.
6. Allen S. Hall Jr., Kinematics and Linkage Design, Prentice Hall, 1961.
7. Ghosh. A and Mallick, A.K., Theory of Mechanisms and Machines, Affiliated East West Pvt. Ltd., New Delhi, 1988.
8. Rao.J.S. and Dukkipati.R.V. Mechanisms and Machine Theory, Wiley-Eastern Ltd., New Delhi, 1992.

Course Name- ***Product Design and Development***
Course Code- ***ME 631***

Course Outcome:

CO1: Understand the Product Design, Phases of Product Development, Design for Assembly (DFA), Design for Manufacturing (DFM).

CO2: Analyze the Theory of inventive problem solving (TRIZ) and Emphasis on the powerful process of innovative problem solving.

CO3: Understand the Manufacturing Considerations in Design systems.

CO4: Understand the Additive Manufacturing (AM) and Rapid Prototyping.

Unit I: Product Design

- Prospect identification
- Customer Requirements/Customer Experience
- Generation-Development-Evaluation" of multiple concepts enabling definition of Product Architecture, form, function, styling, design language, size, variability, durability, reliability, performance & Ergonomics.
- CAD softwares & Digital product development Simulations tools
- Environmental sustainability/"cradle to cradle" approach
- Ergonomics
- Creation of Bill of material (BoM)
- DFM/DFA overview
- Testing & Validation
- Managing Intellectual Property Rights (IPR)

Unit II: Product Development

- Phases of Product Development: Product strategy definition, Product Planning, Product Design, digital & physical testing and validation, Tooling/ Fixture development, Pre-Production, Manufacturing & Sales
- Product strategy definition
- Product Planning
- Competition assessment
- Technical and commercial evaluation of concepts
- Digital & physical testing and validation
- Production readiness and Introduction to Market
- Detailed design consideration of cast, forged, machined, sheet metal, rubber parts etc.

- DFX: Design for Assembly (DFA), Design for Manufacturing (DFM), Design for Inspection (DFI), Design for Variability (DFV) & Design for Cost(DFC)
- Product costing
- Scenarios of Product design Economics

Unit III: Theory of inventive problem solving (TRIZ)
- Fundamentals, methods and techniques, General theory of innovation and TRIZ, Application of value engineering in Product design and development, Model based technology for generating innovative ideas.

Unit VI : Design Thinking
- Emphasis on the powerful process of innovative problem solving which begins with latent/ unmet customer needs with a process of innovation to converge on enhancing success rate of innovation**.**

Unit V: Manufacturing Considerations in Design
- Design for manufacture
- GD&T - Geometric Dimensioning & Tolerances including location, Runout. Profile, Orientation & form.
- Processing techniques and limitations for metals, polymers and ceramics. Influence of materials in processing and tooling on the design of components.
- Finishing, surface coatings and surface modifications of materials.
- Design for accuracy, locating pins and registers, machining in assembly, adjustment. Backlash and clearance adjustment.

Unit VI: Introduction to Additive Manufacturing (AM) and Rapid Prototyping
- Different AM processes & process chain
- Application level: Direct processes; Rapid Prototyping, Rapid Tooling. Rapid Manufacturing; Indirect Processes - Indirect Prototyping.
- Reverse engineering
- Impact of AM on "Time to market"

Text Books/References:

1. Ashby, M. F. "Materials Selection in Mechanical Design", Pergaman Press, 1992.
2. Bralla J., "Handbook of Product Design for Manufacture", McGraw Hill, 1988.
3. Levy S., and Dubois, L. H, "Plastics Production Design Engineering Handbook, Methuen Inc., 1985.
4. Dieter G E, Engineering Desing, McGraw-Hill, 1991.
5. Yotaro Hatamura, The Practice of Machine Design, Claredon Press Oxfor, 1999.
6. Ertas Atilia and Jones J C, The Engineering Design Process, John Wiley & Sons, 1996.
7. Waldron B M and Kenneth J W, Mechanical Design: Theory and Methodology, Spriinger, 1996.
8. Ian Gibson, David W. Rosen and Brent Stucker, Additive manufacturing technologies: rapid prototyping to direct digital manufacturing, Springer, 2010.

Course Name- ***Design Optimization***
Course Code- ***ME 632***

Unit I: Introduction-Design Characteristics of Mechanical Elements - Adequate and Optimum design - Principles of optimization - Conventional Vs Optimal design process - Design variables - Formulation of objective function – Design constraints - Variable bounds - Classification of Engineering optimization problem.

Unit II: Single Variable Optimization Techniques-Optimality Criteria - Bracketing Methods - Exhaustive search method - Bounding phase method – Region Elimination Methods - Interval halving method - Fibonacci search method - Golden section search method - Gradient based Methods - Newton - Raphson method - Bisection method - Secant method - Cubic search method.

Unit III: Multi Variable and Constrained Optimization Techniques-Optimality criteria - Direct search Method - Simplex search methods - Hooke-Jeeve's pattern search method - Powell's conjugate direction method - Gradient based method - Cauchy's method - Newton's method - Conjugate gradient method. Kuhn - Tucker conditions - Penalty Function - Concept of Lagrangian multiplier - Complex search method - Random search method

Unit IV: Intelligent Optimization Techniques-Introduction to Intelligent Optimization - Soft Computing - Working principles of Genetic Algorithm Types of reproduction operators, crossover & mutation, - Simulated Annealing Algorithm - Particle Swarm Optimization (PSO) - Graph Grammer Approach - Example Problems

Unit V: Engineering Applications-Structural applications - Design of simple truss members. Design applications - Optimum design of simple axial, transverse loaded members - Optimum design of shafts - Optimum design of springs. Dynamic applications - Optimum design of single, two degree of freedom systems and gear vibration absorbers. Mechanisms applications - Optimum design of simple linkage mechanisms

Text Books/References:

1. Jasbir S Arora, *Introduction to Optimum design*, Mechrawhill International, 2011.
2. S. S.Rao, *Engineering Optimisation: Theory and Practice*, Wiley- Interscience, 2008.
3. K. Deb, *Optimization for Engineering design algorithms and Examples*, Prentice Hall of India Pvt. 2005.
4. C.J. Ray, *Optimum Design of Mechanical Elements*, Wiley, John & Sons, 2007.
5. R.Saravanan, *Manufacturing optimization through intelligent techniques*, Taylor & Francis Publications.

Course Name- ***Mechanical Behavior of Materials***
Course Code- ***ME 633***

Unit I: Introduction to deformation behaviour- Concept of stresses and strains, engineering stresses and strains, Different types of loading and temperature encountered in applications, Tensile Test - stress – strain response for metal, ceramic and polymer, elastic region, yield point, plastic deformation, necking and fracture, Bonding and Material Behaviour, theoretical estimates of yield strength in metals and ceramics.

Unit II: Elasticity Theory- The State of Stress and strain, stress and strain tensor, tensor transformation, principal stress and strain, elastic stress-strain relation, anisotropy, elastic behaviour of metals, ceramics and polymers.

Unit III: Yielding and Plastic Deformation- Hydrostatic and Deviatoric stress, Octahedral stress, yield criteria and yield surface, texture and distortion of yield surface, Limitation of engineering strain at large deformation, true stress and true strain, effective stress, effective strain, flow rules, strain hardening, Ramberg- Osgood equation, stress - strain relation in plasticity, plastic deformation of metals and polymers.

Unit IV: Microscopic view of plastic deformation- crystals and defects, classification of defects, thermodynamics of defects, geometry of dislocations, slip and glide, dislocation generation - Frank Read and grain boundary sources, stress and strain field around dislocations, force on dislocation - self-stress, dislocation interactions, partial dislocations, twinning, dislocation

movement and strain rate, deformation behavior of single crystal, critical resolved shear stress (CRSS), deformation of poly-crystals - Hall-Petch and other hardening mechanisms, grain size effect - source limited plasticity, Hall-Petch breakdown, dislocations in ceramics and glasses.

Unit V: Fracture- Fracture in ceramics, polymers and metals, different types of fractures in metals, fracture mechanics – Linear fracture mechanics -KIC, elasto-plastic fracture mechanics - JIC, Measurement and ASTM standards, Design based on fracture mechanics, effect of environment, effect of microstructure on KIC and JIC, application of fracture mechanics in the design of metals, ceramics and polymers.

Unit VI: Deformation under cyclic load- Fatigue- S-N curves, Low and high cycle fatigue, Life cycle prediction, Fatigue in metals, ceramics and polymers.

Unit VII: Deformation at High temperature- Time dependent deformation - creep, different stages of creep, creep and stress rupture, creep mechanisms and creep mechanism maps, creep under multi-axial loading, microstructural aspects of creep and design of creep resistant alloys, high temperature deformation of ceramics and polymers.

Text Books/References:

1. J. Roesler, H. Harders,and M. Baeker,"Mechanical Behaviour of Engineering Materials: Metals, Ceramics, Polymers, and Composites", Springer- Verlag, 2007.
2. W.K. Liu, E.G. Karpov, H.S. Park, "Nano Mechanics and Materials", John Wiley and Sons Pvt. Ltd, 2006.
3. Thomas H. Courtney, "Mechanical Behavior of Materials", McGraw-Hill, 1990.

Course Name- ***Experimental Stress Analysis***
Course Code- ***ME 634***

Unit I: Measurements & Extensometer-Principles of measurements, Accuracy, Sensitivity and range of measurements. Mechanical, Optical Acoustical and Electrical extensometers and their uses, Advantages and disadvantages.

Unit II: Electrical Resistance Strain Gauges-Principle of operation and requirements, Types and their uses, Materials for strain gauge. Calibration and temperature compensation, cross sensitivity, Rosette analysis, Wheatstone bridge and potentiometer circuits for static and dynamic strain measurements, strain indicators.

Unit III: Photoelasticity-Two dimensional photo elasticity, Concept of light – photoelastic effects, stress optic law, Interpretation of fringe pattern, Compensation and separation techniques, Photo elastic materials. Introduction to three dimensional photo elasticity.

Unit IV: Brittle Coating and Moire Methods-Introduction to Moire techniques, brittle coating methods and holography.

Unit V: Non–Destructive Testing-Fundamentals of N DT, Radiography, ultrasonic, magnetic particle inspection, Fluorescent penetrant technique, Eddy current testing, Acoustic Emission Technique.

Text Books:

1. Srinath, L.S., Raghava, M.R., Lingaiah, K., Garagesha, G., Pant B., and Ramachandra, K., Experimental Stress Analysis, Tata McGraw-Hill, New Delhi, 1984.

Reference Books:

1. Dally, J.W., and Riley, W.F., Experimental Stress Analysis, McGraw-Hill Inc., New York, 2005, IV edition.
2. Hetyenyi, M., Hand book of Experimental Stress Analysis, John Wiley and Sons Inc., New York, 1972.
3. Pollock A.A., Acoustic Emission in Acoustics and Vibration Progress, Ed. Stephens R.W.B., Chapman and Hall, 1993.

Course Name- ***CAD***
Course Code- ***ME 635***

Unit I: CAD Hardware and Software, Types of systems and system considerations, input and output devices, hardware integration and networking, hardware trends, Software modules,

Unit II: Computer Communications, Principle of networking, classification networks, network wring, methods, transmission media and interfaces, network operating systems,

Unit III: Computer Graphics Introduction, transformation of geometric models: translation, scaling, reflection, rotation, homogeneous representation, concatenated transformations; mappings of geometric models, translational mapping rotational mapping, general mapping, mappings as changes of coordinate system; inverse transformations and mapping;

Unit IV : Projections of geometric models, orthographic projections, Geometric Modeling, curve representation: Parametric representation of analytic curves, parametric representation of synthetic curves, curve manipulations. Surface representation,

Unit V : Fundamentals of solid modeling, boundary representation (B-rep), Constructive Solid Geometry (CSF), sweep representation, Analytic Solid Modeling (ASM), other representations; solid manipulations, solid modeling based applications: mass properties calculations, mechanical tolerancing, etc.

Unit VI: Finite Element Modeling and Analysis, Finite Element Analysis, finite element modeling, mesh generation mesh requirements, semiautomatic methods, fully automatic methods, design and engineering applications, System Simulation, Need of simulation, areas of applications, when simulation is appropriate tool / not appropriate, concept of a system, components of a system, discrete and continuous systems, model of a system, types of models, types of simulation approaches

Text Books/References:

1. Ibrahbim Zeid, "CAD / CAM Theory and Practice".
2. Jim Browne, "Computer Aided Engineering and Design".
3. P. Radhakrishnan / V. Raju / S. Subramanyam, "CAD / CAM / CIM".
4. P.N. Rao, "CAD / CAM principles and applications", Tata Mcraw-Hill, 2002.
5. Rogers / Adams, "Mathematical Elements for Computer Graphics".
6. Rooney and Steadman, "Principles of Computer Aided Design", Aug. 1993.

Course Name- ***MEMS - Design, Fabrication, and Characterization***
Course Code- ***ME 636***

Unit I: MEMS Fabrication-Conventional MEMS fabrication using VLSI technology: lithography, chemical etching: isotropic and anisotropic, Plasma etching, reactive ion etching (RIE), oxidation, chemical vapour deposition (CVD), LPCVD, PECVD, surface micromachining, LIGA, single layer and higher layer fabrication. Non-conventional MEMS fabrication: laser micromachining and welding, processing of metals and nonmetals with laser, Electro Discharge and Electro Chemical micromachining (EDM and ECM), Microstereolithography: scanning process, dynamic mask process. Electronic packaging.

Unit II: MEMS: Design and Analysis-Basic concepts of design of MEMS devices and processes, Design for fabrication, Other design considerations, Analysis of MEMS devices, FEM and Multiphysics analysis, Modeling and simulation, connection between molecular and continuum mechanics, MEM system level analysis from perspective of control theory.

Unit III: MEMS Characterization-Technologies for MEMS characterization, Scanning Probe Microscopy (SPM): Atomic Force, Microscopy (AFM), Scanning tunnelling microscopy (STM), Magnetic Force Microscopy, Scanning Electron Microscope, Laser Doppler vibrometer, Electronic Speckle Interference Pattern technology (ESPI). Examples and case studies: Comb actuator for nanopositioning stage by POLYMUMPS process.

Text Books/References:

1. Nadim Maluf, An Introduction to Microelectromechanical Systems Engineering, Artech House, Boston, 2000.
2. Stephen D. Senturia, Microsystems Design, Kluwer Academic Publishers, New York, November 2000
3. S. M. Sze, VLSI Technology, McGraw-Hill International Editions, Singapore, 1988.
4. M.Elwenspoek and H. Jansen, Silicon Micromachining, Cambridge University Press, Cambridge, UK, 1998.
5. Norio Taniguchi, editor Nanotechnology, Oxford University Press, Oxford, UK, 2003.
6. Joseph McGeough, editor Micromachining of Engineering Materials,Marcel Dekker, Inc., New York, 2002.
7. Marc Madou, "Fundamentals of Microfabrication: The science of miniaturization," CRC Press, LLC, 2002.

Course Name- ***Design of Pressure Vessels***
Course Code- ***ME 637***

Unit I: Introduction-Methods for determining stresses – Terminology and Ligament Efficiency – Applications.

Unit II: Stresses in Pressure Vessels-Introduction – Stresses in a circular ring, cylinder – Membrane stress Analysis of Vessel Shell components – Cylindrical shells, spherical Heads, conical heads – Thermal Stresses – Discontinuity stresses in pressure vessels.

Unit III: Design of Vessels-Design of Tall cylindrical self-supporting process columns –Supports for short, vertical and horizontal vessels – stress concentration – at a variable Thickness transition section in a cylindrical vessel, about a circular hole, elliptical openings. Theory of Reinforcement – pressure vessel Design. Introduction to ASME pressure vessel codes

Unit III: Buckling Of Vessels-Buckling phenomenon – Elastic Buckling of circular ring and cylinders under external pressure – collapse of thick walled cylinders or tubes under external pressure – Effect of supports on Elastic Buckling of Cylinders – Buckling under combined External pressure and axial loading.

Text Books/References:

1. John F. Harvey, Theory and Design of Pressure Vessels, CBS Publishers and Distributors, 1987.
2. Henry H. Bedner, Pressure Vessels, Design Hand Book, CBS publishers and Distributors, 1987.
3. Stanley, M. Wales, Chemical process equipment, selection and Design. Buterworths series in Chemical Engineering, 1988.
4. William. J., Bees, Approximate Methods in the Design and Analysis of Pressure Vessels and Piping, PreASME Pressure Vessels and Piping Conference, 1997.

Course Name- ***Warship Transmission and Tribology***
Course Code- ***ME 641***

Course Outcome:

CO1: Students will be able to **analyze and apply** basics of power transfer in Marine gear boxes, stresses, noise and modes of failure in gear drives

CO2: Students will be able to **explain** about Navel standards used in design of shafting in marine engines transmission system.

CO3: Students will be able to **analyze & apply** different types of hydrodynamic bearings starting from basic governing equations and estimate performance of rolling contact bearings

CO4: Student will **understand** basics of tribology, lubricants used in marine engines & modern lubrication

Syllabus Details	Outcome
Unit I	CO1
Unit II	CO2
Unit IV	CO3
Unit III & V	CO4

Unit I: Warship Transmission Design- Specifications, design and design checks of Marine Gearboxes (Spur and helical gears, Gear Tooth loads, Bearing loads, Reaction torque, Causes and classification of gear failures, gear noise and stress analysis).

Unit II: Shafting- Shafting (NES requirements, torsional and bending strength calculations), Shaft-line Bearings (NES requirements, types, numbers and load distribution), Clutches and Couplings

Unit III: Tribology- Theory of wear, its types and reduction, Theory of hydrodynamic lubrication, properties of marine lubricants.

Unit IV: Bearings- Classification, selection and performance. Theories of design of Journal Bearings and Rolling element bearings with performance and life estimation

Unit V: Modern Lubrication, Surface treatment.

Text Books/References:

1. Engineering Tribology, GW Stachowiak, AW Batchelor, Butterworth Heinman, 2001.
2. Shigley's Mechanical Engineering Design [In SI Units], Joseph Shigley, Charles Mischke, Richard Budynas, Keith Nisbett, Tata McGraw Hill, 2008.
3. Schaum's Outline of Machine Design, 3rd Ed, Tata McGraw Hill, 2010.
4. Gear Engineering, Pitman, Merritt HE, Latest edition.

Course Name- ***Automatic Control Systems***
Course Code- ***ME 642***

Course Outcome:

CO1: Students will understand basics of control systems like transfer function, closed/open systems, feedback & feed forward systems & draw block diagrams for mechanical, electrical and hydraulic systems

CO2: Students will understand Nyquist criterion, static & dynamic characteristics of transient, steady state, 1st/2nd order control systems using frequency response, stability analysis, root locus analysis.

CO3: Students will understand control system actions & components like discrete/proportional, integral & differential control actions, comparators & actuators, amplifiers, servo motors, control valves

CO4: Students will be able to apply control system basics to pneumatic, hydraulic & electrical systems based on microprocessor, PLC, micro-controller based distributed Marine control systems

Syllabus Details	Outcome
Unit I	CO1
Unit II	CO2
Unit III	CO3
Unit IV & V	CO4

Unit I: Basic concepts of Automatic Control- Transfer Functions-Modeling of systems- Mechanical, Electrical, hydraulic system block diagram, signal flow graphs, closed and open loop systems. Feedback and Feed forward control system.

Unit II: Static and Dynamic Characteristics of Control Systems- Transient Response and Steady state error analysis for First and second order systems. Frequency response. Experimental determination of transfer function. Stability Analysis. Root Locus Analysis. Nyquist Criteria.

Unit III: Control Actions and Control System Components- Discrete action, Proportional, Integral and Differential Control Action, Composite action. Characteristics, working and limitations of different types of Comparators and actuators, amplifiers, Servo motors and Control valves.

Unit IV: Control System Implementations- Pneumatic Systems, Hydraulic Systems, Electrical Systems, Microprocessor Based Systems, Programmable Logic Controllers, Micro Controllers and Network Based Distributed Control Systems,

Unit V: Case Studies- Marine Systems (for Naval Students): Integrated Platform Management System / Battle Damage Control System, Ship board digital control, architecture and implementation of control of Marine systems in the latest Indian Naval Surface Warships.

Mechanical Systems (for Non - Naval Students): Engine auto control warning system, NBC & fire fighting systems, Remote vehicles.

Texts Books:

1. Measurement System, Application & Design, 4thEd, E O Doebelin, Mc Graw Hill, 2003.
2. Modern Control Engineering, 4th Ed, Katushiko Ogata, Pearson, UK, 2001.

3. Modern Control Engineering, 4th Ed, Katushiko Ogata, Pearson, UK, 2001.

Course Name- ***Ship Dynamics and Marine Systems***
Course Code- ***ME 643***

Course Outcome:

CO1: Students will be able to **explain & apply** basics of ship structure, stability and design

CO2: Students will be able to **analyze, explain & apply** procedures for Staff requirements and procurement of main and auxiliary machineries

CO3: Students will be able to **explain & apply** basics of marine systems like Distillation & Desalination Plants, Power Generation, Air conditioning & Refrigeration

CO4: Students will be able to **explain & apply** Damage Control, NBCD requirements, Instrumentation and controls of a ship

Syllabus Details	Outcome
Unit I	CO1
Unit II	CO2
Unit III	CO3
Unit IV & V	CO4

Unit I: Introduction to Naval Architecture and Ship Dynamics- Categorization of ships, ships geometry and hydrostatics, Properties of ship building materials, Strength and structure of ship's hydrostatics and initial stability. Intact and Damage Stability. Ship Powering Calculations and Propeller design.

Unit II: Staff Requirements for new ship design- Formulation of requirements, general role, speed, endurance, armament, logistic requirements, procedure for formulating outline, agreed and approved staff requirements, procedure for finalization of ship designs. Choice & Selection of Propulsion System and Auxiliaries

Unit III: General requirements of marine machinery Design for shock protection. Types of main propulsion and their evaluation. Selection of Distillation & Desalination Plants, Power Generation, Air conditioning & Refrigeration, Ships Systems,

Unit IV: NBCD Requirements, Marine Controls and Instrumentation.

Unit V: Trials: Sea trials, their requirements and procedures.

Texts Books

1 Introduction to Naval Architecture, TC Gilmer, Bruce Johnson, Naval Institute Press, 1982.
2 Basic Ship Theory, Vol I & II, Rawson & Tupper, Saint Louis, Butterworth Heineman, 1994.
3 Warship Propulsion System Selection, CM Plumb, The Institute of Marine Engineers, 1987.

Course Name- ***Marine Diesel & Steam Engines***
Course Code- ***ME 644***

Course Outcome:

CO1: Students will be able to **analyze** & **apply** basic reactive thermodynamics and **explain** requirements of marine diesel engine design

CO2: Students will be able to **analyze, apply and explain** Marine Diesel Engine rating, selection & engine-propeller matching

CO3: Student will be able **analyze and explain** regulations & control Mechanisms for noise and emissions control from marine diesel engines

CO4: Students will be able to **understand, analyze & apply** basic working characteristics, performance & basic design considerations of boilers & steam turbines using thermodynamic charts/relations

Syllabus Details	Outcome
Unit I	CO1
Unit II	CO2
Unit III	CO3
Unit IV & V	CO4

Unit I: Basic Concepts- Reactive Thermodynamics, complete and incomplete combustion, volumetric efficiency. Design Requirements, Materials, Types of Supercharging

Unit II: Marine Diesel Engine rating, selection, engine-propeller matching- Terminology, Service Rating, Corrections for ambient conditions, Diesel engine Characteristics, Principles of matching, Modifications to allow for Service conditions, Towing Loads, Auxiliary Loads, CPP.

Unit III: Noise and Emission Reduction in marine engines- Regulations, Constituents, Control Mechanisms for reduction of noise and exhaust emissions from marine diesel engines.

Unit IV: Boiler Design- Boiling process, heat transfer and fluid flow dynamics, boiler design considerations, procedure. Steam cycles analysis: Steam turbine thermodynamics, Simple Rankine cycle, Power output and efficiency calculations, measures to improve cycle performance parameters.

Unit V: Steam turbines-Impulse and reaction turbines, multistaging in turbines, compounding of turbines, design and part load performances, turbine losses. Steam turbine design procedure.

Texts Books

1. Internal Combustion Engine Fundamentals, JB Heywood, McGraw Hill , 2003.
2. Internal Combustion Engine Theory and Practices, 2nd Ed, Vol I & 2, Charles Fayette Taylor, MIT Press, 1999.
3. Steam Turbines: Theory and Design, Shlyakhin P, Foreign Languages Publishing House, Moscow, 1995.

Course Name- ***Marine Gas Turbines***
Course Code- ***ME 645***

Course Outcome:

CO1: Students will be able to **analyze, apply & explain** basic working of marine gas turbines in terms of its thermodynamic and mechanical behaviour

CO2: Students will be able to **analyze, apply & explain** aerodynamic & mechanical design & performance characteristics of gas turbines and compressors

CO3: Students will be able to **analyze, interpret & explain** mechanical design requirements of Marine gas turbine components & recommend suitable materials for its manufacturing

Syllabus Details	Outcome
Unit I	CO1
Unit II & III	CO2
Unit IV & V	CO3

Unit I: Gas Turbine theory and Performance: Gas dynamics, thermodynamic and fluid mechanics concepts, Gas Turbine Types and application, Cycle Analysis & Performance. Design & off- design point performance, Transient performance of single shaft, two shaft engine with FPT. Gas Turbine Simulation. Compressor turbine Matching. Propeller matching, displacing equilibrium running line.

Unit II: Turbo Machinery Aerodynamics Design: Compressor design and Performance - Pressure losses separation & friction losses, Definition delta upon D, De Hallers no. Stage loading and flow parameters, degree of

reaction, stall, Use of IGVs & VGVs, multi-spooling, variable temp rise distribution. Compressor design co-relations & example.

Unit III: Mechanical Design and Performance of Turbine and Compressors: Blade shapes, methods of design. Velocity triangles, reaction, stage loading, flow coefficient. Design for maximum power. Stage efficiency, over-tip leakage. Design correlations & example. Centrifugal, Gas, Inertia Loads acting on turbo-machinery,

Unit IV: Creep design, Fatigue design, Requirements of naval application. Marine GT Combustors Design.

Unit V: Design & Materials for Marine GTs. Requirements, properties, Super-alloys, Manufacturing, Marine coatings, Types & Process. Marine GT Systems Design requirements & Integration with ships systems.

Texts Books/References

1. Gas Turbine Theory, 5th Ed, Cohen, Rogers & Sarvamuttu, John Wiley & Sons, 2001.
2. Fluid Mechanics and Thermodynamics of Tubomachinery, SL Dixon, 6th Ed, Elsevier, 2010.
3. Gas Turbine 2nd Ed, V Ganeshan, Tata McGraaw Hill, 2010.
4. Fundamentals of Gas Turbines, 2nd Ed, Bathie WW, John Wiley, 2003.
5. The Design of Hi-efficiency Turbomachinery and Gas Turbine, DG Wilson & T Korakianitis, MIT Press, 2002.

Course Name- Nuclear Reactor Engineering
Course Code- ME 646

Course Outcome:

CO1: Students will **understand &** be able to **apply** basic knowledge of nuclear physics

CO2: Students will be able to demonstrate **understanding** on safety aspects related to functioning of a nuclear reactor

CO3: Students will be able to **analyse, apply and explain** thermal and hydraulic design aspects of nuclear reactor systems

CO4: Students will **understand &** be able to **explain** basics of control and instrumentation of an nuclear reactor

Syllabus Details	Outcome
Unit I	CO1
Unit II	CO3
Unit III & IV	CO2
Unit V	CO4

Unit I: Nuclear Reactor Physics: Introduction to nuclear physics: nuclear fission, nuclear reactions and radiations. Reactor analysis, reactor kinetics and control,

Unit II: Nuclear Reactor Engineering: Thermal & hydraulic aspects of reactor design, energy removal. Core and Fuel design. Reactor process system, reactor fuel design. Design aspects of major reactor components, material selection, shielding design. Overview of nuclear fuel cycle. Different reactor systems,

Unit III: Nuclear Reactor Safety: Overview of nuclear safety philosophy, defense in depth principle, different safety systems,

Unit IV: Health Safety: Effects of different types of radiation, dosage, radiation monitoring.

Unit V: Nuclear Reactor Control & Instrumentation: General features of reactor control, control in reactor operation. Basics of reactor instrumentation, instrumentation range and wide range of detectors used. Visit to BARC Mumbai for one day.

Texts Books

1. Nuclear Reactor Engineering: Reactor Design Basics, Volume – 1, Samuel Glasstone and Alexander Sesonske, CBS Publishers and Distributors, 2002.
2. Nuclear Reactor Engineering: Reactor systems engineering, Volume - 2, Samuel Glasstone and Alexander Sesonske, CBS Publishers and Distributors, 2002.
3. Introduction to Nuclear Engineering, John R. Lamarsh and Anthony J. Baratta. Prentice Hall; 3rd editions, 2001.

Course Name- ***Convective Heat & Mass Transfer***
Course Code- ***ME 654***
Course Outcome:

CO1: Students will be able to **explain, analyze & apply** basic conduction & convection principles

CO2: Students will be able to **analyze & apply** internal & external forced convection concepts to real life problems.

CO3: Students will be able to **apply** & **explain** basic concepts of radiation & mass transfer. **Understand** non-dimensional parameters affecting convective mass transfer in combined heat & mass transfer processes like boiling & condensation

Syllabus Details	Outcome
Unit I & II	CO1
Unit III & IV	CO2
Unit V & VI	CO3

Unit I: Basic concepts of convection
Energy Equation, Generalized approach to energy equations, Dimensionless Groups, Velocity and thermal Boundary layer, Equation for thermal boundary layer: Scaling analysis of steady flow over flat plate, Significance of Prandtl number
Unit II: External Laminar Forced convection
Thermal boundary layer equation (Pohlhausen solution), Approximate solution for flat plate boundary layer problem, Flow past cylinder: Strouhal number, Average Nusselt number
Unit III: Internal Laminar Forced convection
Thermally fully-developed flow, Energy balance, Constant wall temperature case, constant wall heat flux case, Hydrodynamically & Thermally developed flow with constant wall heat flux, Graetz problem: Hydrodynamically developed & Thermally developing flow with constant wall heat flux
Unit IV: Natural/Free and Mixed convection
Free convection over vertical flat plate, Grashof number, conditions for free/forced/mixed convection, free convection for vertical cylinder, Introduction to Mixed convection: Thermal expansion number, Archimedes number, Froude number
Unit V: Condensation and Boiling
Introduction, film condensation on a vertical plate, average heat transfer coefficient, Laminar film condensation inside and outside of horizontal tubes, Introduction to boiling, modes of boiling
Unit VI: Mass Transfer
Introduction, Conservation of species for a control volume, mass diffusion equation, concentration boundary layer, Schmidt number, Sherwood number, Lewis number, Heat and mass transfer analogy, Evaporative cooling

Practice: Solve thermal boundary layer over flat plate using Matlab/C/python code

Text Books:
I. Introduction to Convective Heat Transfer Analysis by Patrick H. Oosthuizen and David Layor (McGrow-Hill)
II. Convective Heat and Mass Transfer by Kays, Crawford and Weigand (4th Edition, McGraw-Hill)
III. Convective Heat Transfer by L C Burmeister (Wiley)
Reference Books:
I. Convective Heat Transfer by Adrian Bejan (4th Edition Wiley)
II. Boundary Layer Theory by H Sctllichting (McGraw-Hill)
III. Heat and Mass transfer by Eckert ERG and Drake RM (Translated by J P Gross, McGrow-Hill)

IV. Convective Heat Transfer: Solved Problems by Michel Favre-Marinet and Sedat Tardu (Wiley)

Course Name- ***Performance Testing and Instrumentation***
Course Code- ***ME 655***

Unit I: Performance testing of Machinery Sea Water Cooling, Lube Oil Fill/Transfer/Purification Systems, - Main Propulsion Lube Oil System, Starting Air Compressors and System, Ship Service and Control Air Equipment, Segregated Ballast System, Steam and Condensate System, Fuel Oil Service System, Fuel Oil Quick Closing Valves, High Temperature/Low Temperature Fresh Water Cooling Systems, Stern Tube Lube Oil System,

Unit II: Performance testing of Ship Service Generator Operational Tests, Emergency Diesel Generator , Batteries and Chargers, Lighting System Operation, Navigation and Signal Lights, Radio Communication Equipment, Ships Whistles, Tank Level Indicators, Auxiliary Boiler and Services, Fire and Foam System, Machinery Bilge and Oily Waste Transfer System

Unit III: Fundamental & Importance of Instrumentation, types of instruments, selection of instruments, performance of instruments, error in measurement, calibration & standard, Calibration of Instruments: Methods & analysis, Introduction to Transducer & types, Process Instrumentation, recording instruments, indicating & recording Instruments.

Unit IV: Measurements of temperature, pressure, relative humidity, moisture content & velocity & flow.

Text books/Reference:

1. Experimental Methods, J.P. Holman McGraw Hill International, Auckland
2. Engineering Metrology, R KJain, Khanna Publishers, Delhi
3. Mechanical Measurements, Thomos G. Beckwith and I.ewis Back N. Adison Wesely Longman, Harlow
4. Industrial lnstrurnentation, John Wiley Eastern Ltd, New Delhi

Course Name- ***Marine Hydrodynamics***
Course Code- ***ME 657***

Course Outcome:

CO1: Understand and review of Ideal and viscous incompressible fluid; Kinematics of fluid; Lagrangian and Eulerian methods of description, velocity, acceleration, streamlines, pathlines, vorticity

CO2: Understand the basic Two dimensional motion - velocity potential, stream function, Sources, sinks, dipoles; Flow past a circular cylinder with and without circulation; Blausius Theorem

CO3: Understand The vortex system-circular vortex, two dimensional sources and vortex distributions, vortex sheets; Lifting Surfaces, Aerofoil theory; Velocity and pressure distribution on aerofoils; Viscous fluids-Navier-Stokes equations, Laminar flow, Poiseuille flow, Couette flow

CO4: Understand Gravity waves- Airy's wave; Free surface condition; Velocity potential- Dispersion relation; Surface tension effects; Orbital motion; Group velocity and its dynamical significance; Wave energy

Syllabus Details	Outcome
Unit I	CO1
Unit II	CO2
Unit III	CO3
Unit IV	CO4

Unit I: Ideal and viscous incompressible fluid; Kinematics of fluid; Lagrangian and Eulerian methods of description, velocity, acceleration, streamlines, pathlines, vorticity; Equation of continuity; Euler's Equations of motion; Bernoulli's equation and its application,

Unit II: Two dimensional motion - velocity potential, stream function, Sources, sinks, dipoles; Flow past a circular cylinder with and without circulation; Blausius Theorem; Problems on the motion of perfect fluids - steady translation of a cylinder in an infinite fluid medium, unsteady translation; Added mass of cylinders; Spheres;

Unit III: The vortex system-circular vortex, two dimensional sources and vortex distributions, vortex sheets; Lifting Surfaces, Aerofoil theory; Velocity and pressure distribution on aerofoils; Viscous fluids- Navier-Stokes equations, Laminar flow, Poiseuille flow, Couette flow, flow through a pipe; Boundary layer Theory-Reynolds Number; Boundary layer along a flat plate; Blasius solution; Separation, Von Karman momentum integral method;
Unit IV: Introduction to Turbulence; Gravity waves- Airy's wave; Free surface condition; Velocity potential-Dispersion relation; Surface tension effects; Orbital motion; Group velocity and its dynamical significance; Wave energy; Standing waves; Loops and nodes, Wave forces and Morison's equation, Long waves and waves in a canal; Tides.

Text Books:

1. Lamb, H. (1995) Hydrodynamics, 6th Edition, Cambridge University Press, USA
2. Newman, Nick, (1977) "Marine Hydrodynamics" MIT Press.

References:

1. Frank, White (2005) Viscous Fluid Flow, McGraw-Hill Education; 3RD edition.
2. Milne-Thomson, L. M. (1996) Theoretical Hydrodynamics, Dover Publications, Inc. New York. Introduction to Fluid Mechanics
3. Dean, R. G. & Dalrymple, R. A. (2001) "Water Wave Mechanics for Engineers and Scientists" Allied Publishers Limited, New Delhi (Reprint of World Scientific, Singapore).

Course Name- ***Additive Manufacturing***
Course Code- ***ME658***

Unit I: Review of solid modeling techniques with comparison. Product development. Simultaneous Engineering and Additive Manufacturing(AM). Basic Principle of AM processes.
Unit II: Support structure in Additive Manufacturing. Containment and critical applications. Generation of the physical layer model. Classification of AM Processes.
Unit III: Virtual Prototyping. Tessellation (STL format) and tessellation algorithms. Defects in STL files and repairing algorithms. Slicing and various slicing procedures.
Unit IV: Accuracy and Surface quality in Additive Manufacturing. Effect of part deposition orientation on accuracy, surface finish, build time, support structure, cost etc. Various Rapid tooling techniques. Introduction to Reverse Engineering. Reverse engineering and Additive Manufacturing.

Text /References*:*

1. Ian Gibson, David W. Rosen and Brent Stucker, Additive manufacturing technologies: rapid prototyping to direct digital manufacturing, Springer, 2010.
2. C.K. Chua, K.F. Leong and C.S. Lim, Rapid prototyping: Principles and applications, 3 rd Edition, World Scientific, 2010
3. Andreas Gebhardt, Understanding additive manufacturing: rapid prototyping, rapid tooling, rapid manufacturing, Hanser Publishers, 2011.
4. L. Lu, J. Fuh and Y. S. Wong, Laser-induced materials and processes for rapid prototyping, Kluwer Academic Press, 2001.
5. Zhiqiang Fan and Frank Liou, Numerical modeling of the additive manufacturing (AM) processes of titanium alloy, lnTech, 2012.

Course Name- ***Rapid Prototyping***
Course Code- ***ME 659***

Unit I: Introduction- History, Development of RP systems, Applications in Product Development, Reverse Engineering, Rapid Tooling, Rapid Manufacturing- Principle, Fundamental, File format, Other translators, medical applications of RP, On demand manufacturing, Direct material deposition, Shape Deposition Manufacturing.

Unit II: Liquid Based and Solid Based Rapid Prototyping Systems:
Classification, Liquid based system, Stereolithography Apparatus (SLA), details of SL process, products, Advantages, Limitations, Applications and Uses. Solid based system – Fused Deposition Modeling, principle, process, products, advantages, applications and uses – Laminated Object Manufacturing.

Unit III: Powder Based Rapid Prototyping Systems- Selective Laser Sintering – principles of SLS process, principle of sinter bonding process, Laser sintering materials, products, advantages, limitations, applications and uses. Three Dimensional Printing – process, major applications, research and development. Direct shell production casting – key strengths, process, applications and uses, case studies, research and development. Laser Sintering System, e-manufacturing using Laser sintering, customized plastic parts, customized metal parts, e-manufacturing – Laser Engineered Net Shaping (LENS).

Text Books

- Rafiq I. Noorani, Rapid Prototyping, "Principles and Applications", Wiley & Sons, 2006.
- Chua C.K, Leong K.F and Lim C.S, "Rapid Prototyping: Principles and Applications", Second Edition, World Scientific, 2003.

References:

- N.Hopkinson, R.J.M, Hauge, P M, Dickens, "Rapid Manufacturing – An Industrial revolution for the digital age", Wiley, 2006
- Ian Gibson, "Advanced Manufacturing Technology for Medical applications: Reverse Engineering, Software conversion and Rapid Prototying", Wiley, 2006
- Paul F.Jacobs, "Rapid Prototyping and Manufacturing : Fundamentals of Stereolithography", McGraw Hill 1993.
- Pham. D.T., and Dimov. S.S., "Rapid Manufacturing", Springer Verlog 2001.

Course Name: ***Heat Exchanger Design***
Course Code: ***ME660***
Course Outcome:

CO1: Understand the basics of Heat exchangers, its classification of different applications. Introduction to Thermal and hydraulic aspects, pressure drop and heat transfer, sizing and rating, LMTD and NTU method etc.

CO2: Understand role of Biot number and its significance in Fin design, lumped parameter analysis, effectiveness, efficiency and thermal resistance of fins. Understand different types of heat exchangers. Evaluate Fouling and corrosion and its effect on heat transfer and pressure drop and calculations for shell and tube heat exchanger.

CO3: Analyze the different components and their functions in connection Heat Pipe and Phase change heat exchangers and apply the understanding to the design of future systems.

CO4: Understand and evaluate the requirement of Heat Exchanger packaging and testing and proposing solution to the existing problems persisting in current inventory of combat vehicles.

Unit I: Introduction to Heat Exchangers: Introduction, Application of Heat exchangers, Classification of heat exchangers, Types of heat exchangers, common terminologies, Introduction to Thermal and hydraulic aspects, pressure drop and heat transfer, sizing and rating, LMTD and NTU method

Unit II: Fin Design: Biot number and its significance, Applicability of Lumped parameter analysis, Fins and its design, Effectiveness and efficiency, Heat transfer from fin array, Thermal resistance concept

Unit III: Heat Exchanger Design: Shell and Tube Heat Exchangers, Fin tube heat exchanger, Plate Fin Heat Exchangers (PFHE), Direct contact heat exchangers, Regenerators and Recuperator, types of regenerators, construction, application, Theory of Regenerator

Unit IV: Fouling and corrosion: Effect of fouling on heat transfer and pressure drop, Fouling mechanisms, single phase liquid side, single phase gas side, Prevention of fouling, Types of corrosion, corrosion control, advantages and disadvantages of water as a medium in heat exchangers

Unit V: Advanced topics: Heat Pipe and Phase change heat exchanger: Heat pipes, construction, working principle, application, and analysis. Special heat pipes, Phase change heat transfer, Phase change heat-exchangers (Evaporators and Condensers)

Unit VI: Heat Exchanger packaging and testing: Heat Exchanger packaging, Air elimination unit, Air blower/ fan power requirements, Safety valves, Heat Exchanger testing: Steady state and dynamic methods

Text Books:

1. Fundamentals of Heat Exchanger Design by Ramesh K. Shah & Dusan P. Sekulic (John Wiley & Sons)
2. Heat Exchangers: Selection, Rating, and Thermal Design by Sadik Kakaç, Hongtan Liu, Anchasa Pramuanjaroenkij (CRC Press)
3. Heat Exchanger Design by Arthur P. Fraas, Fraas (Wiley)

Reference Books:

1. Heat Exchanger design handbook by T. Kuppan
2. Compact Heat Exchangers by William M. Kays andA.L. London, (Krieger Publishing Company)
3. Fundamentals of heat transfer - Frank P. Incropera, David P. DeWitt

Course Name- ***Computational Fluid-Structure Interaction and its Applications***
Course Code- ***ME 661***

Course Outcome:

CO1: Understand the real-life problems of Fluid-Structure Interactions (FSI) and fundamental of governing equations and boundary conditions. Learn Fundamentals of Computational Fluid Dynamics (CFD) using Finite Volume and Finite Element techniques.

CO2: Understand and evaluate Fluid-structure Coupling and Interface handling: Fluid-structure coupling algorithm-Partitioned coupling schemes, Arbitrary Euler-Lagrange (ALE).

CO3: Analyze the different modules and their functions available in AUTODYN software for simulation of coupled Fluid-Structure Interaction problems.

CO4: Understand and evaluate different real-life problems through simulation using ANSYS AUTODYN software.

Unit I: Introduction: Fluid-Structure Interactions (FSI), Real world examples of FSI, Models of the Flow, Finite Control Volume, Infinitesimal Fluid Element, The Substantial Derivative, Physical meaning of Divergence of the Velocity, Continuity, Momentum and Energy Equations, Equations for Inviscid Flow (the Euler Equations), Comments on governing equations, Physical Boundary Conditions.

Unit II: Fundamentals of Computational Fluid Dynamics (CFD): Basic aspects of Discretization, Introduction of Taylor series, Finite Difference and Finite Volume formulation of steady/transient one-dimensional conduction equation, Consistency, Convergence and Stability, Temporal Discretisation Explicit Schemes Implicit Schemes

Unit-III: Fundamentals of Finite Element Method (FEM): Finite Element Formulation Starting from Governing Differential Equations, Weighted Residual Method, The General Weighted Residual (WR) Statement, Weak (Variational) Form of the Weighted Residual Statement, One-dimensional Finite Element Analysis, One-dimensional Heat Transfer

Unit-IV: Fluid-structure Coupling and Interface handling: Fluid-structure coupling algorithm-Partitioned coupling schemes, Arbitrary Euler-Lagrange (ALE) preliminaries, Kinematics, Fluid equations on a moving domain, Structure equations, Strong vs weak coupling

Unit-V: Introduction to ANSYS AUTODYN: Introduction to Autodyn, Graphical User Interface (GUI), Basic features of Autodyn, Expilict Dynamics Products, Lagrange Solvers, Euler Solvers, ALE (Arbitrary Lagrange-Euler) Solver, Coupling, Contact and Erosion, Using Autodyn in Workbench and as Standalone, Multi-material Euler Solver, Euler-Blast solver, Rigid, Fully and Weak and Polygon coupling, Introduction of material models

Unit-VI: ANSYS AUTODYN Exercise Problems

1. Shaped Charge Impact,
2. Effect of blast in Urban area,
3. Mine blast under a vehicle,
4. Analysis of remotely operated self actuated blast valve,
5. Underwater shock loading of a ship,
6. Penetration of 2000 lbs GP bomb in composite structure,

7. Kinetic Energy Projectile Impact on Reinforced Concrete

Text books/References:

1. Computational Fluid Dynamics the Basics with Applications, Jr., John D. Anderson, ISBN-13: 9780071132107, McGraw Hill Education
2. Textbook of Finite Element Analysis, P. Seshu, PHI Learning Pvt. Ltd, ISBN: 9788120323155, 9788120323155
3. Computational Fluid-Structure Interaction: Methods and Applications, Yuri Bazilevs, Kenji Takizawa, Tayfun E. Tezduyar, ISBN: 978-0-470-97877-1
4. Arbitrary Lagrangian Eulerian and Fluid-Structure Interaction-eBook, M'hamed Souli, ISBN-13: 9781118618684, Wiley
5. ANSYS AUTODYN User's Manual, ANSYS Inc.

Course Name- M. Tech. Dissertation Phase– I
Course Code- ME 651

Course Name- M. Tech. Dissertation Phase– II
Course Code- ME 652
