## B Tech Curriculum – 2022-2026

Flexible Total Credits: 160/168/180/188
Mandatory Learning Courses (MLC): 12 Credits (2+9+1)
Flexible Core - Choice Based Credit System (CBCS)
Provisions for awarding credits to students for their performance in NCC and Major Projects (optional) - OEs
Scope for Component level Self Directed Learning (SDL) in a few courses
Mandatory Mini Project for Minor Specialization

| ACADEMIC YEAR | NO. OF CREDITS | REMARKS |
|---|---|---|
| **FIRST** | 22 + 22 = 44 | EG-I & EG-II – 1 credit each<br>Universal Human Values & professional ethics– 1 credit<br>Human Rights and Constitution – 1 credit |
| **SECOND** | 22 + 21 = 43 | ODD SEM: Core + Labs<br>EVEN SEM: Core + Labs |
| **THIRD** | 21 + 21 = 42 | ODD SEM: FLEXIBLE Core + Labs + OE<br>EVEN SEM: FLEXIBLE Core + OE + PEs + Labs<br>CHOICE BASED CREDIT SYSTEM FOR CORE COURSES<br>MANDATORY OE - CPI |
| **FOURTH** | 18 + 13 = 31 | ODD SEM: PEs + OE<br>EVEN SEM: Project Work/Practice School, Industrial Training |

**FIRST YEAR B Tech CURRICULUM 2022 (Common to all branches)**

**PHYSICS CYCLE**

| Year | FIRST SEMESTER | | | | | | SECOND SEMESTER | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | Sub. Code | Subject Name | L | T | P | C | Sub. Code | Subject Name | L | T | P | C |
| I | | Engineering mathematics - I | 3 | 1 | 0 | 4 | | Engineering mathematics - II | 3 | 1 | 0 | 4 |
| | | Engineering Physics | 2 | 1 | 0 | 3 | | Engineering Chemistry | 2 | 1 | 0 | 3 |
| | | Mechanics of Solids | 2 | 1 | 0 | 3 | | Biology for Engineers | 3 | 0 | 0 | 3 |
| | | Basic Electronics | 2 | 1 | 0 | 3 | | Basic Electrical Technology | 2 | 1 | 0 | 3 |
| | | Basic Mechanical Engineering | 2 | 1 | 0 | 3 | | Problem Solving Using Computers | 2 | 1 | 0 | 3 |
| | | Communication Skills in English | 2 | 0 | 0 | 2 | | Environmental Studies | 2 | 0 | 0 | 2 |
| | | Universal Human Values and Professional Ethics (MLC) | 1 | 0 | 0 | 1 | | Human Rights and Constitution (MLC) | 1 | 0 | 0 | 1 |
| | | Engineering Physics Lab | 0 | 0 | 3 | 1 | | Engineering Chemistry Lab | 0 | 0 | 3 | 1 |
| | | Workshop Practice | 0 | 0 | 3 | 1 | | PSUC Lab | 0 | 0 | 3 | 1 |
| | | Engineering Graphics - I | 0 | 0 | 3 | 1 | | Engineering Graphics - II | 0 | 0 | 3 | 1 |
| | | Creativity, Problem Solving & Innovation*(MLC) | 1 | 0 | 0 | --* | | Creativity, Problem Solving & Innovation* (MLC) | 1 | 0 | 0 | --* |
| | | | **15** | **5** | **9** | **22** | | | **16** | **4** | **9** | **22** |
| | **Total Contact Hours (L + T + P)** | | **29** | | | | **Total Contact Hours (L + T + P)** | | **29** | | | |

*After completing a project work along with other activities which are assessed periodically the students would earn 3 credits which would be considered in lieu of an open elective for Fifth semester B Tech

**FIRST YEAR B Tech CURRICULUM 2022 (Common to all branches)**

**CHEMISTRY CYCLE**

| Year | FIRST SEMESTER | | | | | | SECOND SEMESTER | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | Sub. Code | Subject Name | L | T | P | C | Sub. Code | Subject Name | L | T | P | C |
| I | | Engineering mathematics - I | 3 | 1 | 0 | 4 | | Engineering mathematics - II | 3 | 1 | 0 | 4 |
| | | Engineering Chemistry | 2 | 1 | 0 | 3 | | Engineering Physics | 2 | 1 | 0 | 3 |
| | | Biology for Engineers | 3 | 0 | 0 | 3 | | Mechanics of Solids | 2 | 1 | 0 | 3 |
| | | Basic Electrical Technology | 2 | 1 | 0 | 3 | | Basic Electronics | 2 | 1 | 0 | 3 |
| | | Problem Solving Using Computers | 2 | 1 | 0 | 3 | | Basic Mechanical Engineering | 2 | 1 | 0 | 3 |
| | | Environmental Studies | 2 | 0 | 0 | 2 | | Communication Skills in English | 2 | 0 | 0 | 2 |
| | | Human Rights and Constitution (MLC) | 1 | 0 | 0 | 1 | | Universal Human Values and Professional Ethics (MLC) | 1 | 0 | 0 | 1 |
| | | Engineering Chemistry Lab | 0 | 0 | 3 | 1 | | Engineering Physics Lab | 0 | 0 | 3 | 1 |
| | | PSUC Lab | 0 | 0 | 3 | 1 | | Workshop Practice | 0 | 0 | 3 | 1 |
| | | Engineering Graphics – I | 0 | 0 | 3 | 1 | | Engineering Graphics - II | 0 | 0 | 3 | 1 |
| | | Creativity, Problem Solving & Innovation (MLC)* | 1 | 0 | 0 | --* | | Creativity, Problem Solving & Innovation (MLC)* | 1 | 0 | 0 | --* |
| | | | **16** | **4** | **9** | **22** | | | **15** | **5** | **9** | **22** |
| | **Total Contact Hours (L + T + P)** | | **29** | | | | **Total Contact Hours (L + T + P)** | | **29** | | | |

*After completing a project work along with other activities which are assessed periodically the students would earn 3 credits which would be considered in lieu of the open elective for Fifth semester B Tech

**B Tech in Automobile Engineering**

| Year | THIRD SEMESTER | | | | | | FOURTH SEMESTER | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | Sub. Code | Subject Name | L | T | P | C | Sub. Code | Subject Name | L | T | P | C |
| II | | Engineering Mathematics - III | 2 | 1 | 0 | 3 | | Engineering Mathematics - IV | 2 | 1 | 0 | 3 |
| | | Strength of Materials | 2 | 1 | 0 | 3 | | Automotive Component Design | 3 | 1 | 0 | 4 |
| | | Materials Science and Metallurgy | 3 | 0 | 0 | 3 | | Manufacturing Techniques & Metrology | 3 | 0 | 0 | 3 |
| | | Engineering Thermodynamics | 3 | 1 | 0 | 4 | | Linear Control Theory | 2 | 1 | 0 | 3 |
| | | Fluid Mechanics | 3 | 1 | 0 | 4 | | Vehicle Transmission Systems | 2 | 1 | 0 | 3 |
| | | Basics of I C Engines | 3 | 0 | 0 | 3 | | Autotronics | 3 | 0 | 0 | 3 |
| | | Geometric Modelling Lab | 0 | 0 | 3 | 1 | | Materials Testing Lab | 0 | 0 | 3 | 1 |
| | | Automobile Lab – I | 0 | 0 | 3 | 1 | | Automobile Lab – II | 0 | 0 | 3 | 1 |
| | | | | | | **22*** | | | | | | **21*** |
| | **Total Contact Hours (L + T + P)** | | **26** | | | | **Total Contact Hours (L + T + P)** | | **25** | | | |

*The departments may interchange the credits of Third and Fourth semesters based on need

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**B Tech in Automobile Engineering**

| Year | FIFTH SEMESTER | | | | | | SIXTH SEMESTER | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | Sub. Code | Subject Name | L | T | P | C | Sub. Code | Subject Name | L | T | P | C |
| III | | Engineering Economics and Financial Management | 3 | 0 | 0 | 3 | | Essentials of Management | 3 | 0 | 0 | 3 |
| | | Vehicle Chassis Systems | 2 | 1 | 0 | 3 | | Vehicle Dynamics and Control | 3 | 1 | 0 | 4 |
| | | **Flexible Core I**<br>Industrial IoT **(A)**<br>Finite Element Methods **(B)**<br>Advanced Engine Technology **(C)** | 3 | 0 | 0 | 3 | | **Flexible Core II**<br>Machine Learning and AI **(A)**<br>Computational Fluid Dynamics **(B)**<br>Theory of Vibrations **(C)** | 2 | 1 | 0 | 3 |
| | | Heat Transfer | 3 | 1 | 0 | 4 | | PE – 1 / Minor Specialization | 3 | 0 | 0 | 3 |
| | | Electric Vehicle Technology | 3 | 0 | 0 | 3 | | PE – 2 / Minor Specialization | 3 | 0 | 0 | 3 |
| | | OE – Creativity, Problem Solving and Innovation** (MLC) - mandatory | 3 | 0 | 0 | 3 | | OE – 1** (MLC) | 3 | 0 | 0 | 3 |
| | | Simulation Lab | 0 | 0 | 3 | 1 | | Automotive Design and Analysis Lab | 0 | 0 | 3 | 1 |
| | | Automobile Lab – III | 0 | 0 | 3 | 1 | | Vehicle Aerodynamics Lab | 0 | 0 | 3 | 1 |
| | | | | | | **21** | | | | | | **21** |
| | **Total Contact Hours (L + T + P)** | | **25** | | | | **Total Contact Hours (L + T + P)** | | **25** | | | |

*Courses of three independent tracks A, B, C to be identified by the department

** Performance of students to be recorded in Eighth semester grade sheet?

**B Tech in Automobile Engineering**

| Year | SEVENTH SEMESTER | | | | | | EIGHTH SEMESTER | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | Sub. Code | Subject Name | L | T | P | C | Sub. Code | Subject Name | L | T | P | C |
| IV | | PE – 3 / Minor Specialization | 3 | 0 | 0 | 3 | | Industrial Training (MLC) | | | | 1 |
| | | PE – 4 / Minor Specialization | 3 | 0 | 0 | 3 | | Project Work | | | | 12 |
| | | PE – 5 | 3 | 0 | 0 | 3 | | Project Work (B Tech – honours)* (V - VIII sem) | | | | 20 |
| | | PE – 6 | 3 | 0 | 0 | 3 | | B Tech – honours Theory – 1* (V semester) | | | | 4 |
| | | PE – 7 | 3 | 0 | 0 | 3 | | B Tech – honours Theory – 2* (VI semester) | | | | 4 |
| | | OE – 2** (MLC) | 3 | 0 | 0 | 3 | | B Tech – honours Theory – 3* (VII semester) | | | | 4 |
| | | Mini Project (Minor specialization)*** | | | | 8 | | | | | | |
| | | | | | | **18/26*** ** | | | | | | **13/33*** |
| | **Total Contact Hours (L + T + P)** | | **18/26*** ** | | | | **Total Contact Hours (L + T + P)** | | **13/33*** | | | |

*Applicable to eligible students who opted for and successfully completed the B Tech – honours requirements

** Performance of students to be recorded in Eighth semester grade sheet?

***Applicable to students who opted for minor specialization

## Minor Specialisation

**Automotive System Engineering**

- Connected Vehicle Systems
- Advanced Drivetrain Systems
- Engine Tribology
- Actuation Systems

**Vehicle System Design**

- Engine Systems Design
- Automotive Ergonomics
- Fatigue Failure and Analysis
- Noise, Vibrations and Harshness

**Program Electives**

- Automotive Pollution Control
- Automotive Thermal Management Systems
- Composite Materials and Structures
- Computer Integrated Manufacturing
- Crashworthiness and Safety
- Design for Manufacturing
- Digital Manufacturing
- Earth Moving Equipment and Farm Machinery
- Electrochemical Energy Storage Systems
- Experimental Mechanics
- Human Factors in Automotive Engineering
- Industrial Automation and Robotics
- Lean Manufacturing
- Metrology & Measurements
- Numerical Methods for Scientific Computing
- Operations Research
- Optimization Techniques in Engineering
- Statistical Quality Control and Reliability
- Surrogates and Approximations in Engineering Design
- Total Quality Management
- Tyre Technology
- Vehicle Embedded Systems

OPEN ELETIVES:

- Introduction to Automobile Engineering
- Alternatives Fuels for Sustainable Environment

## III SEMESTER

### AAE***: STRENGTH OF MATERIALS [3 0 0 3]

Shear force and bending moment in statically determinate beams; Shear force and bending moment diagram; sign convention, SFD and BMD for standard cases, Stresses in Beam; theory of simple bending, relationship between bending stresses and radius of curvature, relationship between moment and radius of curvature, moment carrying capacity of section, shearing stresses in beams, shear stress for standard section. [10]

Torsion: Circular shafts, Power transmission, torsion of tapered shaft, shaft in series and parallel, strain energy in torsion, combined bending and torsion. [6]

Deflection of beams: Introduction, equation of elastic curve, sign convention, method to calculating deflection, double integral method, Macaulay's Method, area moment method, conjugate beam method, strain energy application; Maxwell's reciprocal theorem. [6]

Thin cylinder and spheres: thin cylindrical vessel subjected to internal pressure, stresses in a thin cylinder vessel subjected to internal pressure, Hoop Stress, longitudinal stress, effect of internal pressure on the dimension of the thin cylinder, thin spherical shells, change in the dimensions of the thin spherical shell due to internal pressure. [7]

Thick cylinders and spheres: Stress in thick cylindrical shell, stress in compound thick cylinder, thick spherical shells. [7]

**References:**


1. R. K. Bansal, A Textbook of Strength of Materials. Laxmi Publications, 2010.
2. S. S. Bhavikatti, Strength of Materials, 4th Edition. Vikas Publishing House, 2013.
3. S. S. Rattan, Strength of Materials, McGraw-Hill Education (India) Pvt Limited, 2011.
4. R. Subramanian, Strength of Materials, Oxford University Press, 2005.


### AAE ****: MATERIALS SCIENCE AND METALLURGY [3 0 0 3]

Introduction to Materials Science and Engineering: Materials classification. Crystallography SC, FCC, BCC, HCP structures. APF. Miller indices: miller bravais indices. Crystal structure determination-X-ray diffraction techniques, Microscopic examination. [4]

Imperfections in Crystals: Point defects, line defects, surface defects. Strengthening mechanisms: solid solution strengthening, Work hardening; recovery recrystallization and grain growth. [4]

Solidification of Metals and Alloys : Solid solution, Hume Rothery's rules, Phase diagrams- Phase and Lever Rules relationship of micro Structure and properties, Isomorphous systems eutectic system. Iron- Carbon equilibrium diagram. Development of microstructure in Iron Carbon alloys, Phase transformation in steel. [13]

Heat Treatment: TTT diagram, Heat treatment of steel, Annealing, tempering, austempering, martempering, Hardenability, surface hardening methods. [6]

Applications of Ferrous alloys, Non-Ferrous Alloys, ceramics and other materials: Steel: low, medium, high carbon steels. Stainless steels-ferritic, austenitic, martensitic, duplex steels-tool steels. Cast iron: gray, white, ductile cast irons. Non-Ferrous alloys: Copper and its alloys. Aluminium and its alloys. Magnesium and it's alloys. Titanium and its alloys. Composite materials: Types of Composite materials, PMCs, MMCs, CMCs, CCCs, and sandwich composites. Ceramics and other materials: Introduction to super alloys, ceramics-PZT –PZLT refractories, composites and glasses. [9]

**References:**


1. Raghavan V, *Material science and engineering*, Prantice Hall India, 2004.
2. Avner Sidney, *Introduction to physical metallurgy*, Mc Graw Hill International, 1991.
3. Shackelford, *Materials science for Engineers*, Prantice Hall New Jersey, 1996.
4. Van Vlack, *Materials science and Engineering*, Addison Wesley, New York, 1989.
5. William D Callister, *Material science and engineering*, Wiley India, 2007.

## AAE ****: ENGINEERING THERMODYNAMICS [3 1 0 4]

Introduction to Thermodynamics Zeroth Law of Thermodynamics – Concept of quality of Temperature – Principles of Thermometry. [6]

First law of Thermodynamics – Corollaries – First law applied to a Process – applied to a flow system – Steady Flow Energy Equation- Limitations of the First Law. [8]

Second Law of Thermodynamics, Kelvin-Planck and Clausius Statements Carnot cycle, Thermodynamic scale of Temperature, Clausius Inequality, Entropy, Availability and Irreversibility, Gibbs and Helmholtz Functions, Maxwell Relations –Third Law of Thermodynamics. [8]

Pure Substances-Mollier Charts, Phase Transformations – Triple point at critical state properties during change of phase, Dryness Fraction – Clausius – Clapeyron Equation Property tables. Mollier charts – Various Thermodynamic processes and energy Transfer – Steam Calorimetry. [10]

Ideal and Real gases- Perfect Gas Laws – Equation of State, Compressibility, Mixtures of perfect Gases Gravimetric and volumetric Analysis, Dalton's Law of partial pressure, Avogadro's Laws of additive volumes, Theory of psychrometry, Atmospheric Air- Specific humidity, Relative humidity, Psychrometric chart. [10]

Performance evaluation of Gas power cycles, Vapor Power cycles, Refrigeration cycles. [6]

**References:**


1. Cenegel Yunus A and Boles Michael, A Thermodynamics, Tata Mcgraw-Hill, New Delhi, 2011.
2. Nag P K, Engineering Thermodynamics, Tata McGraw-Hill, New Delhi, 2006.
3. R K Rajput, A textbook of Engineering Thermodynamics, Laxmi Publications, New Delhi, 2010.
4. Mayhew A. and Rogers B., Engineering Thermodynamics, E.L.B.S. Longman, London, 1994.
5. P L Ballaney, Thermal Engineering, Khanna Publisher, New Delhi, 2012.


## AAE ****: FLUID MECHANICS [3 1 0 4]

Introduction and basic concepts: Classification of fluid flow, no slip condition, velocity profile, Fluid properties Fluid Statics: Hydrostatic law, Pascal law definition, Pressure measurement using manometers (simple and differential manometers), Forces acting on plane, curved surfaces submerged inside fluid. Forces acting on solid objects submerged, floating in fluid (Buoyancy). [10]

Fluid Kinematics and Kinetics (Fluid Dynamics): Fundamentals of Flow Visualization, Types of Motion or Deformation of Fluid Elements Vorticity and Rotationality, Conservation of Mass Conservation of Momentum Conservation of Energy equation, Mass and Volume Flow Rates. [10]

The Bernoulli Equation, differential analysis of fluid flow (Continuity, Navier stokes equations). Dimensional Analysis: Dimensions and Units, Dimensional Homogeneity, Similarity, Buckingham Pi Theorem. Pipe flow: Laminar and Turbulent Flow through pipe, Flow Rate and Velocity Measurement Minor losses, flow rate and velocity measurement. [10]

Flow over bodies: Drag and Lift, Friction and Pressure Drag, Parallel Flow over Flat Plates, Flow over Cylinders and Spheres. Introduction to compressible flow: Stagnation properties, speed of sound and Mach number, shock waves and expansion waves. [6]

**References:**


1. Yunus A Cengel, and Johm M Cimbala, Fluid Mechanics-Fundamentals and Application, McGraw-Hill, 2013.
2. Bansal R.K., A Text Book of Fluid Mechanics and Fluid Machine, Laxmi Publications, 2010.
3. Frank N white, Fluid Mechanics, McGraw Hill, 2011.
4. Bruce R. Munson, Theodore H. Okiishi, Wade W. Huebsch, Alric P. Rothmayer, Fundamentals of Fluid Mechanics, John Wiley and Sons, New Jersey, 2013.
5. Clayton T. Crowe, Donald F Elger, Barbara C Williams,John A Roberson, Engineering Fluid Mechanics, John Wiley and Sons, New Jersey, 2009.

## AAE ****: BASICS OF IC ENGINES [3 0 0 3]

Introduction: Historical Developments of IC Engine, Classifications of IC Engine, 2 stroke and 4 stroke engines, Performance of Engines. [4]

Components of IC Engine: Engine Components, Valve layouts, Valve Timing and Port Timing Diagrams, Scavenging Systems, Valve Actuation Systems, Types of Combustion Chamber, Combustion in SI and CI Engines, Engine knocking, parameters influencing knocking. [9]

Fuel Supply System: Basics of Carburettors, Types of fuel injection systems in SI and CI engine system, Electronic fuel injection system layouts, Governors, Types of Nozzles, Fuel pumps, Spray formation principle. [5]

Ignition System: Requirements of Ignition System, Battery and Magneto Ignition System, Firing order, Ignition timing, spark advance mechanism. [5]

Engine Lubrication and cooling System: Efficiency of IC engine, pumping losses, parameters influencing engine friction, necessity of lubrication, types of lubrication system, types of lubricants, additive used in lubricants , necessity of cooling system, engine temperature distribution, types of cooling system. [5]

Super charging and Turbocharging: Types of superchargers and turbo chargers, Methods of supercharging and turbocharging, effects and limitations of the system. [4]

Engine performance and Testing: Frictional, brake and indicated power measurement system, Air and fuel consumption measurement, engine efficiency, variables affecting engine performance, Numerical on engine performance. [4]

**References:**


1. Ballaney P. L., Theory of Machines, Khanna Publishers, New Delhi, 1998.
2. Richard Stone., Introduction to internal combustion engines, Macmillan Education UK, 2012.
3. Mathur and Sharma, Internal Combustion Engine, Dhanpat rai publications, New Delhi, 2007.
4. Kirpal singh, Automobile Engineering vol II, Standard publishers, 2014.
5. John B. Heyhood, Internal Combustion Engines Fundamentals, McGraw Hill, 2018.
6. V. Ganesan, IC Engines, Tata McGraw Hill Education Private Limited, India, 2012.


## AAE ****: AUTOMOBILE LAB I [0 0 3 1]

Tools and equipment used in Automotive engine servicing and reconditioning, servicing of intake system, Fuel and lubrication system, piston and connecting rod assembly, Engine Valve Reconditioning, , Cylinder bore reconditioning, crank shaft regrinding, cylinder head reconditioning, Engine tune up and assembling following SOPs.

### References:


1. Kirpal singh, *Automobile Engineering,* Vol.2, Standard Publishers distributors, 2011.
2. Tom Denton, *Automobile Mechanical and Electrical systems*, Butterworth-Heinemann publishers, 2011.
3. Dr. N. K. Giri, *Automobile Technology*, Khanna publishers, 2004.


## AAE ****: GEOMETRIC MODELLING LAB [0 0 3 1]

Sketcher Exercises- 2D, Part Modelling tool for 3D Modelling of components and Assembly Exercises, Generative Wireframe and Surface for Surface Modelling.

### References:


1. Sham R Tickoo, CATIA V5:6R2015 for Designers, CADCIM Technologies, 2009.
2. Jaecheol Koh, Catia V5-6r2014 Surface Design: A Step by Step Guide, Create space Independent Publishers, 2015.

## IV SEMESTER

### AAE **** : AUTOMOTIVE COMPONENTS DESIGN [3 1 0 4]

Design of Helical Springs: Introduction to springs. Terms used in compression springs, Spring materials, Derivation of stress and deflection equation in helical springs – cylindrical extension/compression Problems on helical springs Problems on helical springs Stress and deflection in springs of Non-circular wire-Square & Rectangular, Problems Energy stored in springs, Concentric springs, Problems Springs subjected to fluctuating and impact loads, Surge in springs, Problems. [07]

Design of Leaf springs: Introduction, Semi-Elliptical springs-Deflection & Stresses in full length & graduated leaves Stress equalization, Problems on leaf spring Problems on leaf spring Combination of leaf and coil springs, Problems. [07]

Design of Gears: Nomenclature, Standard Involute gears, Beam strength of tooth Lewis' equation. Form factor & velocity factor, Stress in gear teeth, Dynamic loads on gear teeth, Wear Strength. Problems on spur gears. Design of Helical Gear: Nomenclature, Formative number of teeth, Helix angle, Face width, Velocity factor, Static Strength, Dynamic strength, Wear strength Problems on helical gears Design of Bevel Gears: Nomenclature, Straight teeth bevel gears, Virtual number of teeth, Cone angle, Face width Static Strength, Dynamic strength, Wear strength , Problems on Bevel gears Design of Worm Gears : Nomenclature, Materials, Reversibility, Mechanical Advantage, Strength design Efficiency, Heat dissipation, Problems on Worm gears [14]

Design of Bearings: Journal bearings, Viscosity and lubricants, Bearing characteristic number, Sommerfeld number. Coefficient of friction, Bearing modulus, Mechanism of film lubrication, Minimum oil film thickness, Temperature rise, Oil flow, Heat generation & dissipation. Problems on design of journal bearings. Design of Rolling Contact Bearings : Types of ball and Roller bearings, life rating, basic capacities, Equivalent load Loading ratio, factors, Bearing materials, Mounting of bearings, Selection of bearings - problems [10]

Design of Belt Drives: Power transmission, Flat and V belts, Ratio of belt tensions, Centrifugal tension, Factors, Power rating. V-flat drives, Pulleys, Selection of belts and pulleys. Problems on flat and V-belt drives. Design of Wire Rope Drives : Types & construction of wire ropes, Loads & stresses in ropes Problems on rope drives Design of Chain Drives : Types of power chains, Chordal action, Sprocket size & teeth Chain speed, Selection of roller chains, Problems on chain drives Problems on chain drives [10]

**References:**


1. Richard G. Budynass, Keith Nisbett, Shigley's, Mechanical Engineering Design, McGraw-Hill Education, 2015.
2. Robert L. Mott, Machine element in Mechanical Design, Pearson Education, New Jersey, 2004.
3. Robert C. Juvinall, Kurt M. marshek, Fundamentals of Machine Component Design, John Wiley & Sons Inc., 2012.
4. Bhandari V.B, Design of Machine Elements, Tata McGraw-Hill, 2018.
5. Robert L Norton, Machine Design and Integrated approach, Prentice Hall Inc., 2011.


### AAE **** : MANUFACTURING TECHNIQUES & METROLOGY [3 0 0 3]

Introduction to Powder metallurgy, Preparation of powders, Blending, Compaction, Sintering and Finishing operations; Properties of powdered metals - strength, density, ductility, hardness etc., Manufacturing processes of Powder metallurgy; Isostatic pressing, Spark discharge sintering. [8]

Chip less machining; Internal and external thread rolling, Spline rolling, High Energy rate forming processes. Finishing operations; Lapping, Honing, and Super finishing processes, polishing and buffing, Merits, limits and applications. [6]

Introduction, Process principles, Process capabilities, Applications, Advantages and Limitations of - Electromagnetic forming, Explosive forming, Magnetic pulse forming and shearing operations. [4]

Sheet metal operations, Extrusion Process, hot & cold extrusion of bars & tubes, Impact extrusion, hydrostatic extrusion. The drawing process, drawing of rods, bars, tubes and wires. [4]

Characteristics of measuring instruments, elements of an instrument, calibration of instruments, types of error in instruments, selection of instruments, Slip gauges, angle gauges, spirit level, bevel protector, sine bar. [6]

Terminologies in Metrology: precision, accuracy and Sensitivity. Calibration of instruments, types of error in instruments, Concept of Tolerance and interpretation, Taylor's principle of gauge design, GO and No-Go Gauges, Numerical on design of gauges. [6]

Linear and Angular measurements: Use of Slip gauges, Spirit level, Bevel protector, Sine bar, angle gauges. Numerical on Slip and Angle gauges. [2]

**References:**


1. Kalpakjian S, Manufacturing Engineering and Technology, Addison Wesley Publishing, Delhi, 2000.
2. Degarmo paul, Black & Kohser, Materials and Processes in Manufacturing, Prentice Hall of India, New Delhi, 2003.
3. Lindberg R.A, Processes and Materials of Manufacture, Prentice Hall of India, New Delhi, 1991.
4. Dalela S, Manufacturing Science and Technology (Vol. II & III), Umesh Publishers, Delhi, 1998.
5. Jain R K, Engineering Metrology, Khanna Publishers, New Delhi, 2003.
3. Beckwith T H, Mechanical Measurements, Addison Wesley, New York, 1990.


## AAE **** : LINEAR CONTROL THEORY [2 1 0 3]

Introduction: Brief overview of the historical development of Control system theory, Basic terminologies of the control systems, Definition of transfer function. Mathematical modeling of Mechanical and electrical systems to determine the transfer functions. Transfer functions of power amplifiers in different configurations. [4]

Reduction of multiple sub systems: - Development of block diagrams from governing differential equations, Rules for reducing the block diagrams, examples of block diagram reduction into open loop transfer functions of complex systems. Introduction to signal flow graph, Mason's gain formula for finding the transfer function. [8]

Time domain and frequency domain Analysis: - Introduction to time domain analysis, types of signals and their mathematical representation. Time domain response of I and II order systems to different types of signals. Transient response of I and II order systems. Error analysis and its impact on the system output. Introduction to frequency domain analysis and its significance. Graphical techniques- Bode and Polar plots to find the Phase margin and gain margin of the system. [10]

Root locus and stability of systems: - Routh Hurwitz stability criteria and numerical examples. Analysis of control systems via Root locus technique and numerical examples. [8]

State Space analysis: - Introduction to state space techniques. Design a state-feedback controller using pole placement for systems to meet transient response specifications. Determine if a system is controllable and Design a state-feedback controller using pole placement for systems not represented in phase-variable form to meet transient response specifications. [6]

**References:**


1. Ogata, K., Modern Control Engineering, Prentice Hall, V edition, 2009.
2. Norman S Nise, Control systems Engineering, John Wiley,2011
3. Kuo, B.C., Automatic Control System, Prentice Hall, 10th edition, 2019
4. Gopal. M., Control Systems: Principles and Design, Tata McGraw-Hill, 2002.
5. Nagrath & Gopal, Modern Control Engineering, New Ages International, 2021.
6. E. Bryson and Y-C Ho: Applied Optimal Control, Taylor and Francis, 2017.
7. Nagoor Kani, Control Systems Engineering, RBA Publications,2014.


## AAE ****: VEHICLE TRANSMISSION SYSTEM [2 1 0 3]

Vehicle Performance: Introduction to all the components In Automobile Power Train. Different layout of automotive transmission system for four-wheeler, two-wheeler and three wheeler. Derivation of maximum acceleration force and tractive effort on each wheel for different Transmission layout. Various Resistances to Motion of the Automobile, Traction, tractive effort Performance curves, acceleration, grade ability, drawbar pull, Numerical Problems. [6]

Clutch System: Necessity of clutch system, Types of vehicle clutch system, Design of vehicle clutches, clutch materials, clutch actuation system, trouble shooting of clutches, Fluid coupling, modern trends in vehicle clutch, numerical on vehicle clutch system. [9]

Gear System: Necessity of gear box, Calculation of gear ratios, Performance characteristics in different gears, Constructional details of sliding-mesh gear box, Constant-mesh gear box, synchromesh gear box, auxiliary transmissions, compound transmissions, epicycle transmission system, gear ratio estimation, Torque convertor, Modern trends in transmission systems, transfer case, overdrive system, Driving and holding devices, necessity and field of application of one way clutches, trouble shooting of gear box, numerical problems. [9]

Drive to wheel: Introduction to propeller Shaft, propeller shaft vibration, types of joints, angular acceleration of constant velocity joint, types of drives, Differential purpose and principle, limited slip differential, Axles introduction, types of axles, Front wheel drive and Four-wheel drive, trouble shooting of drivelines. [6]

Hydrostatic and Automatic Transmission: Principles of hydrostatic drives, different systems of hydrostatic drives, constant displacement pump and constant displacement motor, variable displacement pump and constant displacement motor and variable displacement motor, variable displacement pump and variable displacement motor, applications, plunger type pump and plunger type motor, advantages and limitations, typical hydrostatic drives, hydrostatic shunt drives. Layouts of automatic transmission, CVT system and components. [6]

**References:**


1. K.Newton,W.Steeds and T.K.Garret, The Motor Vehicle, Butterworth Heinemann, India, 2004.
2. N.K Giri, Automotive Mechanics, Khanna Publication, New Delhi. 2010.
3. Kirpal Singh, Automobile engineering, Vol.1, Standard Publishers, 2007.
4. Harald Naunheimer, B Bertshae, J Rayborz, W Novak, Automotive Transmission Fundamentals, Selection, Design and Application, Second Edition, Springer, 2010.
5. Yi Zhang, Chris Mi, Automotive Power Transmission Systems, Wiley, 2018.


## AAE ****: AUTOTRONICS [2 1 0 3]

Evolution of electronics in automobiles – emission laws – introduction to Euro I, Euro II, Euro III, Euro IV, Euro V standards – Equivalent Bharat Standards. Charging systems: Working and design of charging circuit diagram – Alternators – Requirements of starting system - Starter motors and starter circuits. [8]

Ignition systems: Ignition fundamentals - Electronic ignition systems - Programmed Ignition – Distribution less ignition - Direct ignition – Spark Plugs. Electronic fuel Control: Basics of combustion – Engine fuelling and exhaust emissions – Electronic control of carburetion – Petrol fuel injection – Diesel fuel injection. [8]

Working principle and characteristics of Airflow rate, Engine crankshaft angular position, Hall effect, Throttle angle, temperature, exhaust gas oxygen sensors – study of fuel injector, exhaust gas recirculation actuators, stepper motor actuator, vacuum operated actuator. [8]

Control modes for fuel control-engine control subsystems – ignition control methodologies – different ECU"s used in the engine management – block diagram of the engine management system. In vehicle networks: CAN standard, format of CAN standard – diagnostics systems in modern automobiles. [6]

Traction control system – Cruise control system – electronic control of automatic transmission – antilock braking system – electronic suspension system – working of airbag and role of MEMS in airbag systems – centralized door locking system – climate control of cars. [6]

**References:**


1. Ribbens, Understanding Automotive Electronics, Elsevier, Indian Reprint, 2013.
2. Tom Denton, Automobile Electrical and Electronics Systems, Edward Arnold Publishers, 2000.
3. Barry Hollembeak, Automotive Electricity, Electronics & Computer Controls, Delmar Publishers, 2001
4. Richard K. Dupuy, Fuel System and Emission controls, Check Chart Publication, 2000.
5. Ronald. K. Jurgon, Automotive Electronics Handbook, McGraw-Hill, 1999.


## AAE ****: MATERIAL TESTING LAB [3 0 0 3]

Introduction-Tensile Test, Load-Displacement and Stress-Strain Curves, Torsion Test, Compression Test, Bending Test, Impact Test, Hardness Test, Fatigue and Shear Test, Test on Mechanical Springs, Non-Destructive Testing.

**References:**


1. Timoshenko, S., Strength of materials, Vols. II, Princeton, D.Von Nostrand Co., 2002.
2. Shigley J, Mechanical Engineering Design, McGraw Hill New York, 2011.
3. Mott, Applied Strength of materials, PHI, 2016.

4. Egor P. Popov, Engineering Mechanics of Solids, PHI, 2004.

### AAE ****: AUTOMOBILE LAB-II [3 0 0 3]

Lathe operations, turning, taper turning, thread cutting, gear hobbing, CNC programming, Grinding. Determination of viscosity, flash and fire points, compression ratio, valve-timing diagrams, performance test on petrol and diesel engines, Morse test, Refrigeration test rig.

**References:**

1. M L Mathur and R P Sharma, Internal Combustion Engines, Dhanpat Rai Publications, 2011.
2. V Ganesan, Internal Combustion Engines, Tata McGraw-Hill, 2012.
3. Kalpakjian S, Manufacturing Engineering and Technology, Addison Wesley Publishing, Delhi, 2000.

## V SEMESTER

### AAE ****: VEHICLE CHASSIS SYSTEMS [2 1 0 3]

Introduction: General consideration relating to chassis layout, power location, types of automobiles, layout of an automobile with reference to power plant, weight distribution, stability. [4]

Frames: Types of frames, general form & dimensions, materials, frame stresses, frame sections, cross members, proportions of channel sections, constructional details, loading points, sub frames, passenger car frames, X member type frame, Box section type frame, testing of frames, bending and torsion test, effect of brake application of frame stresses, truck frames, defects, center of gravity of a vehicle, numerical. [4]

Suspension System: Introduction, Functions, Mechanism, Components, Features, Types of Springs, Design of Springs, Types of Suspension system, Types of Independent Suspension system, Dampers, Air Suspension system, hydra gas suspension system, Maintenance aspects of vehicle suspension system. [8]

Vehicle Brake System: Necessity, stopping distance and time, brake efficiency, weight transfer, brake shoe theory, determination of braking torque, energy dissipation, classification of brakes, construction, function, operation, mechanical, hydraulic, disc, drum, details of hydraulic system, mechanical system and components, types of master & wheel cylinders, bleeding of brakes, brake drums, brake linings, brake fluid, factors influencing operation of brakes, brake pad materials, engine brakes, vacuum assisted braking system, parking brakes, air brake system layout and components, maintenance of braking system. [10]

Steering system: Steering geometry, Ackermann Principles, Steering geometry, Steering mechanism components, Types of steering mechanism, Power assisted steering mechanism, four wheel steering mechanism, and maintenance aspects of steering system. [6]

Wheels and Tyres: Types of automobile wheels, Tyre fundamentals and characteristics, Major components, Radial and Cross bias tyre, Types of tread, Vehicle handling, wheel balancing. [4]

**References:**

1. Newton W.Steeds and T.K.Garret, The Motor Vehicle, Butterworth Heinemann, India, 2004.
2. N .K.Giri, Automobile Mechanics, Seventh Edition, Khanna Publishers, Delhi, 2005.
3. Kirpal Singh, Automobile Engineering, Volume 1, Standard Publishers and Distributors, 2007.
4. David C. Barton, John D. Fieldhouse, Automotive Chassis Engineering, Springer, 2018.
1. P.M. Heldt, Automotive Chassis, Chilton & Co, 2012.

### AAE ****: HEAT TRANSFER [3 1 0 4]

Introduction to combustion: Essential condition for proper combustion, Introduction to flames, Classification of flames ,Auto ignition Temperature, Stages of combustion in SI Engines –Flame propagation-Rate of Pressure rise-cycle to cycle variation, CI engine: Droplet and spray combustion theory-stages of combustion, Delay Period – peak Pressure –Heat Release, Gas temperature –Diesel Knock, Different types of combustion chamber for SI and CI engine. [8]

Introduction to heat transfer: Various modes of heat transfer. Governing laws and equation for different modes of heat transfer. Combined mode, conductivity and film coefficient of heat transfer. Thermal diffusivity, overall heat transfer coefficient, thermal resistance and conductance. Linear heat flow through plane wall, composite wall, cylinder, sphere. Heat transfer from fins of uniform cross section having adiabatic tip, Isothermal tip,infinitely long fins. Heat transfer from fins of uniform cross section having Convective tip, Efficiency and effectiveness of fin. Effect of variable thermal conductivity, critical thickness of insulation. [12]

Convection heat transfer: Physical mechanism of convection, Newton's law of cooling, no-slip condition, Classification of fluid flows, Dimensionless numbers – Reynolds number, Nusselt number, Prandtl number. Velocity and thermal boundary layers, surface shear stress, Advantages of dimensional analysis, dimensional homogeneity, fundamental and derived quantities Buckingham pi theorem, selection of repeating variables, Example on Buckingham pi theorem, External forced convection, flow over flat plates, boundary layer thickness, flat plate with unheated length, Internal forced convection, fully developed flow, constant surface temp and heat flux, correlations for laminar and turbulent flows, Mechanism of Natural convection, Grashof number, coefficient of volume of expansion. [14]

Radiation heat transfer: Radiation, black body radiation, Planck's law, Wien's displacement law, radiation intensity, irradiation, radiosity, Spectral quantities, radiative properties, Kirchhoff's law, Shape factor, relations of shape factor, radiation heat transfer between two black surfaces, Radiation heat transfer between two non-black surfaces, radiation shield. [6]

Heat Exchanger: Types of heat exchanger, advantages and disadvantages of each type, various application of heat exchanger, LMTD derivation for parallel and counter flow heat exchanger, NTU derivation for parallel and counter flow heat exchanger, fouling factor. [4]

Boiling and Condensation: Definition and explanation of boiling, types of boiling, pool boiling curve, flow boiling types of condensation heat transfer, Flow regimes for film wise condensation, mechanism of dropwise condensation. [4]

**References:**


1. P.K. Nag, Heat and Mass Transfer, Tata McGraw Hill Education Pvt Ltd, New Delhi, 2011.
2. Yunus Cengel and Afshin Ghajar, Heat and Mass Transfer, Tata McGraw Hill Education Pvt Ltd, New Delhi, 2011.
3. R. K. Rajput, Heat and Mass Transfer, S Chand & Co Ltd. New Delhi, 2006.
4. S K Som, Introduction to Heat Transfer, PHI Learning Pvt Ltd, New Delhi, 2008.
5. J P Holman, Heat Transfer, McGraw Hill, New York, 2010.
6. M L Mathur and R P Sharma, Internal Combustion Engines, Dhanpat Rai publications, New Delhi, 2011.
7. V Ganesan, Internal Combustion Engines, Tata McGraw-Hill Education, New Delhi, 2012.


## AAE ****: ELECTRIC VEHICLE TECHNOLOGY [3 0 0 3]

Overview of electric drive vehicles, Evolution of EVs, Comparison of EVs with Conventional Vehicles, Classification of EVs, applications of EVs, propulsion requirements of EVs, power required for propulsion, Road loads on a vehicle, Torque applied and traction calculations, draw bar pull, Vehicle performance parameters I C engine characteristics, traction Motor characteristics. [5]

Configurations HEVs and EVs, based on hybridness in HEVs, compatibility between energy sources, Power flow modes, architecture of EVs and configurations based on power trains, energy sources , EV and HEV power train sizing, Rating of traction motors and I C engines for set performance parameters [8]

Torque generators for EVs, Electric machine fundamentals, DC machines, Three phase AC machines. Induction machines. Permanent magnet machines. Switched reluctance machines. motor control techniques for EV applications, transmission system requirements in EVs based on motor speed ratio, Power electronic switches and converters. [6]

Energy storage systems for EVs, requirements, classifications, performance parameters, batteries used and proposed for EVs,Li- based batteries, metal air batteries, Na-based batteries, futuristic batteries, battery management, ultra- capacitors, fuel cells, classification, working characteristics, flywheels, comparison of energy storage systems, hybrid energy storage systems for EVs. [6]

Energy management systems for EVs, control systems in EVs, control variables, Master and subsidiary controllers, HEV control systems, offline and online , GPS enhanced Power Management Control [6]

Engine requirements and transmission systems for HEVs, features of I C engines used for HEVs, power coupling devices, torque couplers, speed couplers, configurations of HEVs based on mechanical couplers. [5]

**References:**


1. Iqbal Husain, Electric and Hybrid Vehicles: Design Fundamentals, CRC Press, 2021.
2. James D Halderman, Hybrid and Alternative Fuel Vehicles, Pearson Education, 2012.
3. Allen E. Fuhs, Hybrid Vehicles and the Future of Personal Transportation, CRC Press, 2009.
4. Mehrdad Ehsani, Yimin Gao, Ali Emadi, Modern Electric, Hybrid Electric, and Fuel Cell Vehicles: Fundamentals, Theory, 2009.
5. John German, Hybrid-Powered Vehicles, Second Edition, SAE International, 2011.


## Flexible Core – 1

### AAE ****: INDUSTRIAL IOT [2 1 0 3]

Understanding Industrial Internet of Things (IIoT): Industrial Internet of Things and Cyber Manufacturing Systems, Application map for Industrial Cyber Physical Systems, Cyber Physical Electronics production. [8]

Modelling of CPS and CMS: Modelling of Cyber Physical Engineering and manufacturing, Model based engineering of supervisory controllers for cyber physical systems, formal verification of system, components, Evaluation model for assessments of cyber physical production systems. [10]

Architectural Design Patterns for CMS and IIoT: CPS-based manufacturing and Industries 4.0., Integration of Knowledge base data base and machine vision, Interoperability in Smart Automation, Enhancing Resiliency in Production Facilities through CPS. Communication and Networking of IIoT [8]

Artificial Intelligence and Data Analytics for manufacturing: Application of CPS in Machine tools, Digital production, Cyber Physical system Intelligence, Introduction to big data and machine learning and condition Monitoring [5]

Application of IIoT: Smart Metering, e-Health Body Area Networks, City Automation, Automotive Applications, Home Automation, Smart Cards, Plant Automation, Real life examples of IIOT in Manufacturing Sector. [5]

**References:**


1. Ismail Butun, Industrial IoT Challenges, Design Principles, Applications, and Security, Springer, 2020.
2. Giacomo Veneri Antonio Capasso Hands-On Industrial Internet of Things: Create a powerful Industrial IoT infrastructure using Industry 4.0, Ingram short title publications, 2018.
3. Sandeep Misra, Chandana Roy, Anandarup Mukherjee Introduction to Industrial Internet of Things and Industry 4.0, Taylor and Francis, 2021.
4. Sabina Jeschke, Christian Brecher Houbing Song, Danda B. Rawat Editors Industrial Internet of Things Cyber Manufacturing Systems, Springer, 2016.
5. Dr. Guillaume Girardin , Antoine Bonnabel, Dr. Eric Mounier, Technologies Sensors for the Internet of Things Businesses & Market Trends 2014 -2024,Yole Development Copyrights, 2014.


### AAE ****: FINITE ELEMENT METHOD [3 0 0 3]

Introduction: Origin of FEM, application area, advantages and disadvantages, General steps of finite Element Analysis, types of elements, differential equation involved, analytical and approximate solution. Difference between FEM and FDM(Finite Difference Method), List of different commercial softwares available. [6]

Review of Matrix notation and operations, numerical problems. [6]

Finite Element formulation using principle of minimum potential energy, weighted residual method, Rayleigh-Ritz methods. Numerical problems. [6]

Formulation of 1 dimensional Problem: 1D bar/spring/link equation, truss equation, beam equation, numerical problems. [8]

Formulation of 2 dimensional problems: plane stress plane, strain Constant strain triangular and Linear strain Triangular element FE equation. Numerical problems. [6]

Practical consideration FE analysis, Introduction to contact and large deformation modelling. [4]

**References:**

1. Logan D L, First course in the Finite Element Method, Cengage learning, 2016.
2. Sheshu P., Textbook of Finite Element Analysis, PHI Learning Private Limited, 2003.
3. Robert D Cook, David S Malkus, Micheal E Plesha, Concept and Application of Finite Element Analysis, John Wiley and Sons, 1989.
4. Singiresu S Rao, The Finite Element Method in Engineering, Elsevier Inc, 2018.
5. Saeed Moaveni,Finite Element Analysis:Theory and application with ANSYS, Prentice Hall, 1999.

## AAE ****: ADVANCED ENGINE TECHNOLOGY [3 0 0 3]

Introduction to combustion process in I C engines, Auto ignition temperature, Combustion in SI and CI engines, normal and abnormal combustion, combustion chambers for S I and C I engines. [8]

Emissions from engines, analysis and control, Euro , BS CAFE standards of engines emissions, regulated and secondary pollutants, formation, factors affecting the pollutants in SI and CI engines, Emission analysis, control techniques. [8]

Alternative fuels for I C Engines, Availability and Suitability to Piston Engines, Concept of conventional fuels, potential alternative fuels - Ethanol, Methanol, Hydrogen, LPG, Natural gas, Producer gas, Bio gas and Vegetable oils. [6]

Alternative power plants for modern automobiles, HCCi engines, PCCi engines, Lean burn engines, stratified charge engines, dual fuel engines, Variable compression ratio engines, sterling engine, rotary combustion engine [8]

New trends in engine technology, Tuned intake systems, Intake manifold runner control systems, acoustic supercharging, electronic injection control systems, cylinder deactivation, displacement on demand, Variable Valve Timing, closed loop control system, Variable Geometry Turbochargers, Miller cycle operation, Atkinson cycle operation. Engines for hybrid vehicles [6]

**References:**

1. Colin R. Ferguson, Allan T. Kirkpatrick, Internal Combustion Engine Applied Thermosciences, Wiley, 2015.
2. Richard Folkson, Alternative fuels and advanced vehicle technologies for improved environmental performance, Woodhead Publishing Limited, 2014.
3. N.K.Giri, Automobile Mechanics, Seventh Edition, Khanna Publishers, Delhi, 2005.
4. R. K. Rajput, Non-Conventional Energy Sources and Utilisation, Chand Publishers, 2012.
5. Jack Erjavec, Martin Restoule, Stephen Leroux, Rob D. Thompson, Automotive Technology A Systems Approach, Nelson Education Limited, 2015.

## AAE ****: NUMERICAL SIMULATION LAB [0 0 3 1]

Numerical Computation - Familiarization with MATLAB, Representation of scalars, vectors and matrices, Basic 2D and 3D plot, Locating the roots of equations, Numerical differentiation and integration, Solution of linear and non-linear differential equations, Matrix factorization, Curve fitting, introduction to control system, Stability analysis using Root locus, Bode plot, Nyquist plot and Polar plot techniques, Familiarization with SIMULINK, Control system toolbox, vehicle dynamics toolbox, vehicle network toolbox, communication toolbox, automated driving toolbox, Navigation Toolbox Mass-Spring-Damper Systems, Suspension system modelling, IC Engine modelling, Cruise control, DC Motor position, Motor speed controller, Introduction to electric and hybrid vehicles.

**References:**

1. Robert J. Schilling and Sandra L. Harries, Applied Numerical Methods for Engineers using MATLAB and C, Thomson Learning Inc., 2000.
2. Brian R Hunt, et al, Guide To Matlab: For Beginners And Experienced Users, Cambridge University Press, 2011.
3. Fausett L.V, Applied Numerical Analysis Using MATLAB, Pearson Education, 2007.

### AAE ****: AUTOMOBILE LAB III [0 0 3 1]

Automotive transmission system layouts, clutch, Gearbox, Final drive and differential, steering system, EV and HEV performance testing, wheel balancing, spark plug testing, Head light beam aiming, testing of starter and alternator, wiper motor.

**References:**


1. Kirpal Singh, Automobile engineering –. Vol.2, Standard Publishers distributors, 2011.
2. Tom Denton, Automobile Mechanical and Electrical systems, Butterworth-Heinemann publishers, 2011.
3. Dr. N. K. Giri, Automobile Technology, Khanna publishers, 2004.


### VI SEMESTER

### AAE ****: VEHICLE DYNAMICS AND CONTROL [3 1 0 4]

Introduction to Vehicle Dynamics, Vehicle Coordinates systems, 1 D vehicle dynamics. Forces acting on vehicle for different configurations, level road, gradient, maximum acceleration, numerical. [8]

Vehicle load distribution, Acceleration, braking, Front and rear wheel braking, all wheel braking, car on banked road, brake balance, brake construction, ABS system. [6]

Tyre specifications, construction, types, rolling resistance of tire, Mechanism of force generation in Tyres, hysteresis, Longitudinal slip, cornering properties, camber thrust, slip, camber stiffness. [8]

Conicity & Plysteer in tire, Tire stiffness, Tire vibrations, influence of speed, load, tire pressure on various tire parameters. [5]

Flow phenomenon related to vehicles, External & Internal flow problem, Resistance to vehicle motion – Performance. [5]

Analysis of aerodynamic drag - drag coefficient of cars, Cars as a bluff body-Flow field around car, Low drag profiles, Front end modification, Boat tailing, Hatch back, fast back and square back, Effects of gap configuration, The origin offered and moments on a vehicle, Side wind problems, Vehicle dynamics under side winds. [10]

Principle of wind tunnel technology, Types of wind tunnels and components, Measurement techniques, Similitude in aerodynamics. [6]

**References:**


1. Thomas Schuetz, Hucho.W.H, Aerodynamic of Road vehicles, SAE International, 2016.
2. Mark Gleason, Vehicle aerodynamics design and technology, Society of Automotive Engineers, Incorporated, 2001.
3. Joseph Katz, Automotive Aerodynamics, Wiley Publications, New York, 2016.
4. Thomas D. Gillespie, Fundamentals of Vehicle Dynamics, Revised Edition, R506, Technology & Engineering publication, 2021.
5. Reza N. Jazar, Vehicle Dynamics: Theory and Application by, Springer Science Business Media, LLC, 2008.
6. H. B. Pacejka, Tire and Vehicle Dynamics, 1st Edition Butterworth-Heinemann publication, 2012.
7. Georg Rill: Road Vehicle Dynamics, Fundamentals and Modeling, 1st Edition, CRC press publication, 2012.


## Flexible Core – 2

### AAE ****: MACHINE LEARNING AND ARTIFICIAL INTELLIGENCE [2 1 0 3]

Introduction to Artificial Intelligence: Definition of Artificial Intelligence, Difference between AI and Machine learning, Support Vector machines, Singular value decomposition, Principle component analysis, Linear regression, Logistic regression, Clustering, Decision tree and random forest algorithms, Classification. [6]

Probability theory: What is probability, Probability distributions, Axioms of Probability, Probability Density Estimation, Random variables, Conditional Probability, Chain rule, Bayes rule, Naive bayes, Maximum Likelihood Estimations, Maximum A Posteriori, Hypothesis testing. [8]

Artificial Neural Networks: Biological Neuron, McCulloch-Pitts Neuron Model, Feedforward Network, Hebbian learning rule, Perceptron learning rule, Activation functions, Gradient descent (batch and stochastic), Singe layer perceptron, XOR problem, Multi-layer perceptron, Bias-Variance Trade-off. [8]

Deep learning: Deep learning vs ANNs, Overfitting, Underfitting, Hyperparameter Tuning, Regularization methods, Cross validation, Data augmentation, Convolutional neural networks (CNNs), Layers in a CNN, Recurrent neural networks, Transfer learning, Evaluation metrics. [7]

Popular Dl Architectures: Single Shot Detectors (SSD), You Only Look Once (ZOLO) Architecture Family, Generative Adversarial Networks (GANs), Recurrent Neural Networks (RNNs). [7]

**References:**


1. Stuart J. Russell and Peter Norvig: Artificial Intelligence -A Modern Approach, Pearson, Prentice Hall. Series in Artificial Intelligence, Englewood Cliffs, 2010.
2. Simon Haykin: Neural Networks - A Comprehensive Foundation, Prentice Hall, 1998.
3. Daniel Graupe: Principles of Artificial Neural Networks, World Scientific, 2007.
4. Rich and Knight: Artificial intelligence, Mc Graw Hill India, 2010
5. Jacek M Zurada: Introduction to artificial Neural Systems, West, 1992.
6. Christopher M. Bishop: Neural Networks for Pattern Recognition, Springer, 2007.
7. Aaron Courville, Ian Goodfellow and Yoshua Bengio: Deep Learning: Adaptive computation and machine learning, MIT Press, 2017.


## AAE **** COMPUTATIONAL FLUID DYNAMICS [2 1 0 3]

Governing Equations of Fluid Dynamics: Models of Flow, finite control volume and infinitesimal element approaches. The substantial derivative. Divergence of velocity field and its physical meaning. The continuity equation. Momentum and Energy Equations. Energy Equation in non-conservative format. [4]

General Characteristic of the governing equations: The initial and boundary conditions. Mathematical behavior of different classes of partial differential equations. Equilibrium and Marching behavior. [3]

Discretization Process: Explicit -Taylor series expansion and Discretization of governing equations. Methods of deriving the discretised equations. [4]

The Basic Solution Techniques: Steady state conduction heat transfer. Implementation of boundary conditions and solution. Extension of the method to 1-D Conduction through fin. [4]

Unsteady conduction Heat Transfer: Explicit, Implicit and Crank Nicholson Methods. ADI Methods of solving space and time marching in 2D. [5]

Discretization using Control Volume technique: 1D Diffusion Problems. The Four basic rules in control volume formulation. Dicretization of source terms and linearization of the same. Control volume technique to 2D and 3D steady diffusion flow problems. [4]

Convective flow with diffusion: Numerical methods for steady 1D convective flow with diffusion. Properties of discretization schemes: Conservativeness, Boundedness and Transportiveness. The CDS, the Upwind, and QUICK schemes. Numerical false diffusion with physical examples. [4]

Solution of Pressure linked velocity equations: The need for staggered grid. Flow chart, discussion. The derivation of the pressure correction equation as Poisson's Pressure equation. Implications and implementation. Marker and Cell Explicit Method. [6]

Implementation of Boundary Conditions in CFD: The inlet, exit, outflow and the wall Boundary Conditions. The Constant Pressure, Symmetry and Cyclic BC's. [2]

**References:**


1. John D Anderson Jr., Computational Fluid Dynamics- The Basics with Applications, International Edition. McGraw Hill. New York, 2013.

2. Suhas V Patankar, Numerical Heat Transfer and Fluid Flow, Hemisphere / McGraw Hill New York, 2018.
3. Versteeg H. K., Malalasekera W. An Introduction to Computational Fluid Dynamics- The Finite Volume Method, Longman Scientific & Technical. England, 2007.
4. Anderson D. A, Tannehill J. C, and Pletcher R. H., Computational Fluid Mechanics and Heat Transfer, Taylor and Francis Group. New York, 2020.
5. Chung T. J., Computational Fluid Dynamics, Cambridge University Press South Asia Edition, 2003.
6. Fletcher C. A. J., Computational Techniques for Fluid Dynamics, Vol I and Vol II., Springer- Verlag. Berlin, 2012.

## AAE ****: THEORY OF VIBRATION [2 1 0 3]

Introduction Vibrations and Single degree of freedom systems: Fundamentals, classifications of vibrations Simple harmonic motion, free vibrations, free damped vibrations. Springs in series and parallel combination, governing differential equations of different systems and computing natural frequencies. Damped free vibrations, analyzing systems with over, under and critical damping of systems with viscous damping. Coulomb damping and derivation of differential equation. [10]

Forced vibration of Single degree of freedom systems: - Forced vibrations with and without damping by considering harmonic excitation and rotating unbalance. Base excitation and concept of displacement and force transmissibility ratio and isolation. Force vibration with Coulomb damping. Determining system parameters from Frequency response curves. Deriving peak frequency from experimental curves. Concept of whirling of shafts- undamped and damped case. [12]

2 degree of freedom systems: - Analyzing 2DOF sprig mass undamped system and deriving the natural frequency and concept of mode shapes. Coordinate coupling and numerical examples. Concept of Dynamic vibration and Pendulum absorber. [6]

Multi-degree of freedom systems and continuous system approach: - Analysis of MDOF system by considering spring-mass system, concept of influence coefficients. Determining natural frequency and mode shapes of MDOF systems- by direct approach and numerical methods. Concept of continuous systems and examples. [8]

**References:**

1. Singirisu Rao S, Mechanical Vibration, Pearson Education, Delhi, 2004.
2. Dukkapatti Rao V, Text Book of Mechanical Vibration, Prentice Hall of India Ltd, 2016.
3. Daniel Imnan J., Engineering Vibration, Prentice Hall, New Delhi, 2001.
4. Groover G.K., Mechanical Vibrations, Nemchand And Bros, Roorkee, 2014.
5. Thomson W.T., Theory of Vibrations with Applications, Chapman and Hall, 2011.
6. Seto W.W., Theory and Problems in Mechanical Vibration, MGH, Singapore, 1989.
7. C Sujatha, Vibrations and Acoustics-Measurement and Signal analysis, Mc Graw Hill, India, 2009.

## AAE ****: AUTOMOTIVE STRUCTURAL ANALYSIS LAB [0 0 3 1]

Analysis of Truss/Link Elements, Beam Elements, Shell Elements, Plane Stress/ Plane Strain analysis, 3D Structural analysis, Thermal Analysis, Modal Analysis, Fluid Flow, Acoustic analysis.

**References:**

1. Erdogan Madenci and Ibrahim Guven, The Finite Element Method and Applications in Engineering Using ANSYS, Springer Publications, 2016.
2. Guangming Zhang, Engineering Analysis with Pro/Mechanica and Ansys, College House Enterprises, LLC, 2017.
3. Sham Tickoo, Ansys Workbench 14.0 for Engineers and Designers, Dream Tech Press, US, 2013.

## AAE ****: VEHICLE AERODYNAMICS LAB [0 0 3 1]

Calibration of wind tunnel, drag measurement of cylinder, Flow visualization, Lift calculation of a symmetrical and cambered aero foil, Boundary layer calculations, Wake survey method, six component balance, Analysis of air flow over a vehicle shape.

**References:**

1. Thomas Schuetz, Hucho.W.H, Aerodynamic of Road vehicles, SAE International, 2016.
2. Mark Gleason, Vehicle aerodynamics design and technology, Society of Automotive Engineers, Incorporated, 2001.

### VII SEMESTER

Minor Specialization
Program Electives
Open Electives as mentioned later.

### VIII SEMESTER

### AAE ****: INDUSTRIAL TRAINING [0 0 0 1]

Student is undergoing industrial training for a minimum period of 4 weeks during the vacation. After successful completion of training, student will be submitting a report and presentation on training.

### AAE ****: PROJECT WORK / PRACTICE SCHOOL [0 0 0 12]

The student is required to carry out a project work in the institution / industry / research laboratory / institution of higher learning. The minimum duration of the project work/practice school is 16 weeks. As part of project work / practice school, the student is also required to prepare a project report and make a presentation on the work carried out.

## Minor Specialisation I

## Automotive System Engineering

### AAE ****: CONNECTED VEHICLE SYSTEMS [2 1 0 3]

Basic concepts: Communication terminologies, Communication Fundamentals, Communication technologies and protocols, network architecture, network layers, Communication Between Sensors and Systems. [7]

Communication systems: Analog and digital communication, IEEE standards, Digital electronics fundamentals, Signals and systems basics, wired and wireless communication systems, Fiber optic communication, Satellite Communication and its application in vehicle. [8]

Navigation systems: GPS and RADAR Fundamentals, operation, equation and its types, Mobile Communication, Bluetooth, Ad Hoc networking, Numerical Problems. [6]

Vehicle Communication systems: Mobile Ad Hoc Networking, Vehicular Ad Hoc networking, Local Interconnect Network-Master slave relationship, message format and data formats, Controller Area Network-Message frames, Error handling and CAN controller operations, Intra-vehicular communications, Inter-vehicular communications. [10]

Connected Vehicles: Infotainment system, co-operative driving, connected and autonomous vehicles in smart cities, smart vehicles, intelligent roadways, Case study on modern vehicles systems based on Artificial Intelligence and Machine Learning. [5]

**References:**

1. Gilbert Held, Inter and Intra Vehicle Communications, Auerbach Publications, 2008.
2. Tao Zhang, Luca Delgrossi, Vehicle Safety Communications Protocols, Security, and Privacy, Information Communication technology series, 2012.
3. Mohamed Kassab, Communication Technologies for Vehicles, Springer, 2015.
4. Florian Solzbacher, Jürgen Valldorf, Wolfgang Gessner, Advanced Microsystems for Automotive Applications, Springer Berl Heidelberg, 2003.
5. Hussein T. Mouftah, Melike Erol-Kantarci, and Sameh Sorour, Connected and Autonomous Vehicles in Smart Cities, CRC Press, 2020.
6. Radovan Miucic, Connected Vehicles, Intelligent Transportation Systems, Springer, 2020.

## AAE ****: ADVANCED DRIVETRAIN SYSTEMS [3 0 0 3]

Automotive powertrains, different layouts, drive trains, drive lines, drive, wheel, axle and steering formula designations, generic EV and HEV powertrain layouts. [6]

Power transfer elements: torque transfer systems, design features of plate clutches, torque converter testing and characteristics, Epicyclic gear trains, power split devices, advanced differentials, classification, inter axle and inter wheel differentials, transmission wind-up, final drives, analysis and design. [8]

Advanced gearboxes, dual clutch transmission (DCT) systems, dry and wet DCT mechanisms, Automated manual transmissions, Continuously Variable transmissions, chain/ belt type, CVT control systems, variable force solenoids (VFS), servo mechanism control system, line pressure control, Automatic transmission systems, case studies. [10]

Propeller shafts, design features, U Joints, classification, applications and analysis, drive shafts, classifications and design. [4]

All wheel drive systems, Ferguson Formula, multi axle drive vehicles, transfer cases, classification, Power Take Off devices, classifications. [4]

Vehicle performance and driveline system design, evaluation of consumer and operational properties. [4]

**References:**


1. Robert Fischer, Automotive transmission book, Springer International Publishing Switzerland, 2015.
2. Design Practices: Passenger Car Automatic Transmissions, AE-18, SAE, Warrendale, 1994.
3. YiZhang,Chris Mi, Automotive power transmission systems, Wiley, 2018.
4. Gisbert Lechner, Harald Naunheimer, Automotive Transmissions: Fundamentals, Selection, Design and Application, Springer- Verlag Berlin Heidelberg, New York, 1999.
5. Fenton J., Handbook of Automotive Powertrain and Chassis Design, Professional Engineering Publishing, London, 1998.


## AAE ****: ENGINE TRIBOLOGY [3 0 0 3]

History of Tribology, relevance of subject, Tribology in industry, Friction, Classical Laws of Friction, Theories of Friction, Types of Friction, Effects of friction, Friction measurement, Friction in Metals, Non-metals and Polymers. [06]

Wear, Causes of Wear, Types of Wear, Testing of Wear – debris analysis, testing methods and standards, wear in Metals, Non – metals and Polymers. [06]

Lubrication, Physical properties of lubricants, Types of Viscometers, Viscosity Index, composition, additives, SAE/ISO classification, Lubrication Principles, Lubrication regimes, Stribeck Curve, Hydrodynamic, EHL, Mixed and Boundary Lubrication, Squeeze film lubrication, Reynolds Equation, Pressure formation configurations, Stability of bearings. [08]

Hydrostatic Bearing, Numerical on Power loss, Flow rate, Friction forces and power loss in a lightly loaded journal bearing, Petroff's equation, Numerical on Petroff's equation, Practical applications of lubrication models in engines, Components of IC Engine Subjected to Friction and Wear, Bearing materials, Bearing damages. [08]

Surface texturing in Automotive engines, Grease lubrication in automobiles, Bio Lubricants in Automobiles. [04]

Tribological components in Electric Vehicles - Motor, Rolling bearings, Brushes, Transmission, Gears, Seals, Lubricating oils, Greases, Tyres. [04]

**References:**


4. G. W. Stachowiak and A. W. Batchelor, Engineering Tribology, Butterworth-Heinemann, 2016.
5. B. C. Majumdar, Introduction to Tribology in bearings, Wheeler Publishing, 2010.
6. Prasanta Sahoo, Engineering Tribology, PHI Learning Private Ltd, New Delhi, 2011.
7. Harish Hirani, Fundamentals of engineering tribology with applications, Cambridge University Press, 2016.
8. B. Bhushan, Introduction to Tribology, John Wiley & Sons, Inc., New York, 2002.


## AAE ****: ACTUATION SYSTEMS [3 0 0 3]

Introduction to pneumatic systems: Structure and signal flow of pneumatic systems, Compressors, Air generation and distribution, Constructional details and working of filter, lubricator, and pressure regulator, Advantages and limitations, Applications. [6]

Sensors and Actuators: Symbols of pneumatic valves, types of pneumatic actuators traverse time diagram, Design of manually operated circuits, push buttons, rollers, flow, pressure control valves, time delay, counter circuits, control of multiple actuators. [10]

Electronic actuation systems: Electrically actuated direction control valves, Relay control systems, Design of electro pneumatic circuits, Limit switches, magnetic, inductive, capacitive, optical, ultrasonic, pneumatic proximity sensors, introduction to PLC. [10]

Hydraulic Actuators: Properties of hydraulic fluids, Power pack, Hydraulic Pumps and Motors, Performance of pumps, Accumulator, Application of accumulator, Hydraulic valves, Flow control, directional control and pressure control valves, Design of hydraulic circuits. [10]

**References:**


1. Joji P, Pneumatic Controls, Wiley India Pvt. Ltd, 2013.
2. Majumdar S.R, Pneumatic Systems Principles and Maintenance, Tata McGraw Hill, New Delhi, 2005.
3. Majumdar S.R, Oil Hydraulic Systems Principles and Maintenance, Tata McGraw Hill, New Delhi, 2005.
4. Prede G. and Scholz D., Electro pneumatics Basic Level, Festo Didactic GMBH & Co, Germany, 2012.
5. Peter Croser, Frank Ebel, Pneumatics Basic Level TP 101, Festo Didactic GMBH & Co, Germany, 2012.


## Minor Specialisation II

## Vehicle System Design

### AAE **** : ENGINE SYSTEMS DESIGN [3 1 0 3]

Introduction: Principal parts of an I C Engine, systems of engine, working overview [03]

Cylinders, liners, and cylinder heads: Features of cylinders, dry and wet liners, design of a cylinder, cylinder thickness, bore and stroke, flange and stud design, thickness of cylinder head, problems on cylinder and head design. [05]

Pistons: Function, Materials, Constructional details and design considerations for a piston, design procedure considering the gas loads , thickness at head, open end, barrel, land, grooves, skirt, design of piston rings and piston pin. Problems on piston design [08]

Connecting rods and crankshaft: Functions, materials, types, forces acting on connecting rods, design of connecting rod small end, large end, shank, big end cap and bolts, problems on connecting rod design Functions, materials and manufacture , forces acting, bearing pressure and stresses in shafts, types of crank shafts, design of centre crank shaft and over hung crank shaft, problems on crank shaft design [10]

Valve gear mechanisms and flywheel: Different types of mechanisms, valve requirements, materials, design, thickness of valve disc, stem diameter, valve lift, rocker arm cross section and shaft design, tappet design, valve spring design problems on valves, design of fulcrum pin, push rods. [05]

Hybrid engine components; operation; load/kerb ratio, critical design parameters, Electric vehicles; battery components; selection of battery material; principal of operation; Hybrid vs Electric; Current trends; future scope; Case studies . [05]

**References:**


1. V B Bhandari, Design of Machine Elements, Tata Mcgraw Hill Education, 2010.
2. Newton K, Steeds W, Garrett TK, The Motor Vehicle, SAE Publications, 2004.
3. V Ganesan, Internal Combustion Engines, Tata Mc Graw hill publishing co ltd, 2008.
4. Mahadevan & K. Balaveera Reddy, Design Data Handbook, CBS Publishers & Distributors, 2009.

## AAE***: AUTOMOTIVE ERGONOMICS [3 0 0 3]

Introduction to automotive ergonomics: Ergonomics in vehicle design, ergonomics approach, fitting the equipment to user, designing for most, system approaches, Problem solving methodologies, Ergonomics research studies, ergonomics engineer responsibilities, Origin of ergonomics and human factors, ergonomics in automotive product design, Importance of ergonomics, characteristics of ergonomically designs products, systems and processes., Human characteristics and capabilities, physical capabilities, anthropometric, biomechanical and information processing capabilities, Implementing ergonomics, advanced ergonomics [6]

Engineering anthropometry and biomechanics; Introduction, use of anthropometric design in vehicles, Computation of percentage values, application of biomechanics in vehicle design, Basic biomechanical considerations, biomechanical consideration in seat design, Occupant accommodation and seat comfort related issues, Seat design consideration related to driver accommodation. [5]

Occupant Packaging; Occupant packaging, seat layout, developing occupant packaging: design consideration, Sequence in development of vehicle package, advanced vehicle design stage, flow diagram for ergonomics evaluations, Dimension and reference points, locating the reference points, packaging dimensions, H-point device and H-point Machines, interior dimensions as per SAE J1100, Driver package development procedures.[5]

Control display and interior layout; Introduction, control and display interface, characteristics of good control and good visual display, Types of control and display, in-vehicle controls and classification, In-vehicle display and classification , Design considerations, issues and location principles, general design consideration for display and controls, Control design consideration, visual display design considerations, Control and display location principles, methods of evaluate controls and displays, space availability to locate hand control and display, preparing checklist, Some case study of control and display design issue. [7]

Field view front automotive vehicles; Introduction to field of view, filed of view WRT interior and exterior, date to support required filed view, Types of filed view, direct and indirect filed views, System consideration of 360 degree visibility, monocular, ambinocular and binocular vision, Forward field of view and evaluation, up and down angle evaluation, visibility over the hood, command sitting, short driver and tall driver problems, sun visor design issue, Wiper and defroster requirements, obstructions caused by A-pillar, Mirror design issue and filed requirements, mirror location, procedure for determining driver's field of view through mirrors, Methods of measuring field of view, other visibility issues. [7]

Entry and exit from automotive vehicles; Introduction to entry and exit, problem during entry and exit for vehicles, vehicle features and dimension related to entry and exit, door handle, Door and hinge angles, bolsters, location and materials, seat hardware, Tires and rocker panels, running boards, heavy truck cab entry and exit, Methods to evaluate entry and exit, Task analysis, case study, Case study on the entry and exit of passenger car, Concluding remarks on Ergonomics engineer responsibility [6]

**References:**


1. Vivek D Bhise, Ergonomics in the automotive design process, CRC Press Publications, 2012.
2. Nikolaos Gkikas, Automotive ergonomics – Driver vehicle interaction, CRC Press Publication, 2013.
3. Mark R Lehto, James R Buck, Introduction to human factors and ergonomics for engineers, Taylor and Francis Group publication, 2008.


## AAE ****: FATIGUE FAILURE AND ANALYSIS [3 0 0 3]

Fatigue of Structures: Strength of materials and kinds of failure, importance of failure analysis, procedure for failure analysis, precautions in actual failure analysis S.N. curves, Endurance limit, 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. [10]

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. [8]

Physical Aspects of Fatigue: Phase in fatigue life, Crack initiation, Crack growth, Final fracture, Dislocations, Fatigue fracture surfaces. [6]

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. [6]

Fatigue Design and Testing: Safe life and failsafe design philosophies, Importance of Fracture Mechanics in aerospace structure, Application to composite materials and structures. Case Studies of crane head hanger, wire rope, transmission shaft crank of breaker, fastening screw, gears, piping valves, failure starting from welds in machines and equipment, failure of rolls and rail joints. [6]

**References:**


1. Knott J.F., Fundamentals of Fracture Mechanics, Butterworth & Co., (Publishers) Ltd., London, 1983.
2. Barrois W. and Ripley L., Fatigue of Aircraft Structures, Pergamon Press, Oxford, 1983.
3. Sih C.G., Mechanics of Fracture, Vol.1 Sijthoff and Noordhoff International Publishing Co., Netherland, 1989.
4. Shin-ichi Nishida, Failure analysis in engineering application. Butterworth- Heinemann Ltd publication, 1991.
5. Brock D., Elementary Engineering Fracture Mechanics, Noordhoff International Publishing Co., London, 1994.
6. Charles R. Brooks, Ashok Choudhury, Failure analysis of engineering materials, McGraw-Hill Education, 2002.
7. Yung-Li Lee, Jwo Pan, Richard Hathaway, Mark Barkey, Fatigue Testing and Analysis Theory and Practice, Elsevier Science, 2011.
8. Campbell F. C., Fatigue and Fracture Understanding the Basics, ASM International, 2012.


## AAE ****: NOISE VIBRATIONS AND HARSHSNESS [3 0 0 3]

Introduction: Overview and importance of the subject. Fundamentals of Acoustics-Human Perception of Sound, Sound Wave Propagation in 1-D and 3-D and derivation wave equation. Important Acoustic Quantities and Relations, Sound Transmission from One Medium to Another with Normal Incidence. [8]

Acoustic Transducers and Common Measurements in Acoustics: - Parameters to be Considered in the Choice of Microphones, Various Types of Microphones, Acoustic Exciters and Calibrators. Sound Level Measurement, Sound Power from Sound Pressure Level Measurement- Frequency Weighting Networks, 1/1 and 1/3 Octave Filters. [6]
Exterior noise: assessment and control: - Pass-by noise homologation-EC noise homologation, Track and atmospheric effects, Noise source ranking-using shielding techniques. Air intake systems and exhaust systems: performance and noise effects, The rationale for turbocharging, Sources of intake (and exhaust) noise-Flow duct acoustics, Intake noise control: a case study. [12]

Interior noise: assessment and control: - Subjective and objective methods of assessment, balance between airborne and structure-borne noise, measurement of interior noise, subjective assessment of interior noise. Noise path analysis. Introduction to engine noise-Combustion noise, Mechanical noise, the effects of engine speed and load on noise, Measuring engine noise, Engine noise source ranking, Engine noise control. Introduction to road noise, Interior road noise, Analysing structure-borne road noise, controlling interior road noise. A note on aerodynamic (wind) noise and Brake noise and squeak, rattle and tizz noises. [10]

**References:**


1. Thomson W.T., Theory of Vibrations with Application, Chapman and Hall, 2011.
2. C Sujatha, Vibrations and Acoustics-Measurement and Signal analysis, Mc Graw Hill India, 2009.
3. Matthew Harrison, Vehicle Refinement: Controlling Noise and Vibration in Road Vehicles, Mathew Harrison Publication, 2004.
4. Malcolm J. Crocker, Handbook of Acoustics, John Wiley & sons Publication, 1993.
5. Malcolm J. Crocker, Handbook of Noise and Vibration Control, John Wiley & sons Publication, 2007.

## PROGRAM ELECTIVES

### AAE ****: AUTOMOTIVE POLLUTION CONTROL [2 1 0 3]

Historical background, Regulatory test procedures, European / Bharat stage Emission norms, Carbon and Nitrogen Compounds, Evaporative losses, Analysis of particulates, Exhaust gas pollutants, Particulate pollutants, Analysis of pollutants. [6]

Pollution from Spark Ignition, Compression Ignition engines; Mechanism of formation of various pollutants, Soot in CI engines, Factors affecting emissions in Spark Ignition engines, Compression Ignition engines. Fuel requirements in spark ignition engines and compression ignition engines, Knock and its measurement in spark ignition engines and compression Ignition engines. [8]

Engine Variants- Lean Burn engines, Stratified charge engines, Direct Injection in Gasoline engines, Homogeneous Charge Compression Ignition engines, CRDI technology. Instrumentation for pollution measurements; Desruprsive Infrared analysers, Thermal conductivity and flame ionization detectors, analysers for NOx, Smoke meters, Particulate measuring systems. [10]

Alternative Fuels; Classification- Hydrogen, Natural gas. Properties, storage and performance of engine fuels, vegetable oil and biodiesel. Biomass Energy- Biogas production from organic waste by an aerobic fermentation, Thermo chemical method of bio-conversion-combustion-updraft gasifier, downdraft gasifier. Direct Energy conversion methods; Conversion of thermal energy into electricity – Thermo electric converters, Thermo ionic converter, Conversion of chemical energy into electricity, types of fuel cells, conversion of electromagnetic energy into electricity. [12]

**References:**


1. Ganesan V., Internal Combustion Engines, Tata Mcgraw-hill Education, New Delhi, 2012.
2. Mathur M. L. and Sharma R. P., Internal Combustion Engines, Dhanpat Rai Publications, New Delhi, 2011.
3. Colin R Ferguson and Allan T Kirkpatric, Internal Combustion Engines, Wiley India Ltd, New Delhi, 2004.
4. Willard W Pulkrabek, Engineering Fundamentals of Internal Combustion Engines, PHI learning Pvt Ltd, New Delhi, 2004.
5. Sukatme S. P., Solar Energy Principles of Thermal Collection and Storage, Tata Mc Graw Hill Education, New Delhi, 2005.


### AAE ****: AUTOMOTIVE THERMAL MANAGEMENT SYSTEM [2 1 0 3]

Introduction to heat transfer: Various modes of heat transfer. Governing laws and equation for different modes of heat transfer. Combined mode, conductivity and film coefficient of heat transfer. Thermal diffusivity, overall heat transfer coefficient, thermal resistance and conductanceNumerical. [3]

Types of engine cooling system coolant, forced circulation water cooling system, water pumps, by-pass, radiator hoses, radiator, radiator pressure caps and filler caps, Thermostats, fan and fan drives, Thermo-siphon water cooling system, Air -cooling system, Air-cooled engine, Air-cooling system components advantages of air cooling, temperature indicators. Cooling of all other vehicle components. [9]

History of automotive air-conditioning systems, Introduction to heating and ventilation, the basic theory of cooling, vapour compression refrigeration, the air-conditioning system, the expansion valve system, the fixed orifice valve system, dual air-conditioning, Air-conditioning components, compressor, expansion device, evaporator, condenser, anti-frosting device, basic control switches. [6]

Battery thermal management systems introduction, requirements, necessity, classification, Types of liquid cooled battery thermal management system, advantages and disadvantages of it, types of air-cooled battery thermal management system, PCM for passive battery thermal management, classification of PCM, measurement of thermal properties of PCM, cost and environmental impact of PCM, Methods to improve thermal conductivity of PCM, merits and demerits of PCM cooling, heat pipe cooling, different types of heat pipe, thermoelectric cooling. [12]

Cooling of electronic equipment, Predicting the junction temperature of transistor, determining the junction to case thermal resistance, predicting the junction temperature of device, thermal resistance of an epoxy glass board, conduction cooling of PCBs by a heat frame, cooling of chips by thermal conduction module, cooling of a sealed electronic box, cooling of power transistor on a cold plate by water. [6]

**References:**


1. Yunus Cengel and Afshin Ghajar, Heat and Mass Transfer, Tata Mcgraw Hill Education Pvt Ltd, New Delhi, 2011.
2. N. K. Giri, Automobile Mechanics, New Delhi, 2008.
3. Ibrahim Dincer, Thermal Management of Electric Vehicle Battery Systems, Jhon Wiley and Sons Ltd, United Kingdom, 2017.
4. Steven Daly, Automotive Air conditioning and climate control systems, Elsevier Ltd., United Kingdom, 2006.
5. W P Jones, Air conditioning Engineering, Elsevier Ltd., United Kingdom, 2005.


## AAE ****: COMPOSITE MATERIALS AND STRUCTURES [2 1 0 3]

Classification of composite materials, Characterization of composite materials, Mechanical behavior of composite materials, Basic terminologies of composites. [8]

Review of basic equations of mechanics and materials, Linear elastic model and its application, Stress-strain relations for a unidirectional lamina, Stress-strain relations for isotropic/orthotropic lamina. [8]

Effective Modulii of a continuous fibre reinforced lamina, Models based on mechanics of materials. [8]

Force-Displacement relations for laminates, Laminate stiffness, Single general orthotropic layer, Inter-laminar stresses. [6]

Failure of continuous fiber-reinforced orthotropic lamina, Maximum stress/strain criteria, Tsai-Hill and Tsai-Wu criterion. [6]

**References:**


1. Gibson R. F., Principles of Composite Material, Mechanics, CRC Press, 2016.
2. Kollar L. P., George S Springer, Mechanics of Composite Structures, Cambridge University Press, 2009
3. Agarwal B. D., Broutman L. J. and Chandrashekhara K., Analysis and Performance of Fiber Composites, John Wiley & Sons, 2006
4. R. M. Jones, Mechanics of Composite Materials, Taylor & Francis, 2005.
5. Madhujit Mukhopadhyay, Mechanics of Composite Materials and Structures, Orient Longman, 2004.


## AAE ****: COMPUTER INTEGRATED MANUFACTURING [3 0 0 3]

Introduction, Definition of N.C. Machine, Classification, Advantages and disadvantages of N.C. machine, Design consideration of N.C. Machine tools, general construction requirements, Co-ordinate systems, point to point and contour programming, manual method (word address format only) [6]

NC programming with interactive graphics, manual data input. Problem with conventional NC, Computer Numerical Control, Direct Numerical Control [4]

Introduction to Robotics, Robot anatomy physical configurations, Manipulator Kinematics, Technical features, programming the robot, robot programming language, end effecters, work cell design, work cell control and interlock, robotic sensor, robotic applications. [9]

Types of Manufacturing System, Machine Tools and related equipment, Material Handling System, Flexible Manufacturing System, FMS work station, Types of FMS Layouts, Planning the FMS, Part classification and coding, production flow analysis, machine cell design, benefits of group technology. [9]

Computer aided Process planning, Computer integrated planning systems. Material requirement planning. Capacity planning, shop floor control, factory data collection systems, automatic identification systems – Bar code technology, automated data collection systems. [8]

**References:**

1. Yoram Koren, Computer Control of Manufacturing Systems and Computer Integrated Manufacturing, PHI, New Delhi, 2006.
2. Mikel P Groover, Automation, Production Systems and computer Integrated manufacturing, PHI, New Delhi, 2008.
3. Yoram Koren, Joseph Ben Uri, Numerical Control of Machine Tools, Khanna Publishers, New Delhi, 2005.
4. Mikell P Groover and Emory W Zimmers, Computer Aided Design & Manufacturing, PHI, New Delhi, 2008.

## AAE ****: CRASHWORTHINESS AND OCCUPANT SAFETY [3 0 0 3]

Introduction: Introduction and overview objectives, Motor vehicle safety, Materials and Crashworthiness, Crashworthiness Goals requirements, Crashworthiness tests and Crashworthiness model requirements [6]

Design of Vehicle structure and Crash Energy management: Current design practise, Crash/Crush design requirements for front structures, Analytical design tools, and Vehicle front structure design for different impact modes. Overview of explicit FE technology, Development of FEM technology and limitations of current technology and applications- Component Models, Substructure Models, Full-scale vehicle structure models and Integrated Vehicle-Occupant-Restraints Model. [14]

Fundamental Principles for Vehicle/Occupant systems analysis: - Barrier collision, Basic laws, Application of concept to Vehicle/occupant analysis- Vehicle Response, Pulse Waveform Efficiency and Occupant Response. Axioms for good occupant restraint mechanism- Frontal Impact Analysis, Side Impact Analysis and Effects of Structural Ugrading and cushioning. Compatibility between restraint system and vehicle structure- Belt Restraint System, Supplemental Airbag Restraint System, Ride down concept and application and design methodology- Traditional Method and CAE Methods. [8]

Human Body modeling and Injury Biomechanics from head to toe: - Multi-body method for crash analysis- MADYMO Multi-Body Algorithm, Kinematics of a Rigid Body and flexible body. Crash dummy modeling- Examples of Crash Dummy Databases, modeling the real human body- Examples of a Human Body Model. Injury mechanisms- Head and Neck Injury Mechanisms, Thoracic Injury Mechanisms etc. Mechanical response- Mechanical Response of the Head, Skull. Brain Neck etc., Human tolerance to impact- Head, Neck, Thoracic Injury Tolerance and the remaining body parts. [8]

**References:**

1. Paul Du Bois Clifford C. Chou Bahig B. Fileta Tawfik B. Khalil Albert I. King Hikmat F. Mahmood Harold J. Mertz Jac Wismans, Vehicle Crashworthiness and Occupant Protection, Automotive Applications Committee American Iron and Steel Institute Southfield, Michigan, 2004.
2. CAE Methods for Vehicle Crashworthiness and Occupant Safety, and Safety-critical Systems, SAE special publication: Society of Automotive Engineers, 2004.
3. Narayan Yoganandan, Alan M. Nahum, John W. Melvin, Accidental Injury: Biomechanics and Prevention, The Medical College of Wisconsin Inc, 2015.
4. Jorge A.C. Ambrosio, Crashworthiness: Energy Management and Occupant Protection, Springer-Verlag Wein publication New York, 2001.

## AAE ****: DESIGN FOR MANUFACTURING [3 0 0 3]

Introduction, facts and ideas of design for manufacturing and assembly, product realization process. Classification and compare Design for Manufacture and Assembly Methodologies. Cost relationships, design for serviceability/maintainability. [8]

Design to minimize service requirements. Standardization to minimize part variety, proposing alternative solutions for mistake proof assembly and easy serviceability. Steps to improve design for serviceability / maintainability. [8]

Mechanical and physical properties of metals, plastics. Material selection techniques, Interchangeability of parts with size control. Tolerance analysis and allocation, matching design tolerances with appropriate manufacturing process. Case studies. [10]

Various manufacturing processes Compare the criterion, Case studies; Evaluate design for manufacturing for various casting process, forming process, powder metallurgy process, polymer process, machining, sheet metal forming and related components- Case studies. [10]

**References:**

1. Geoffrey Boothroyd, Peter Dewhurst and Winston A. Knight, Product Design for Manufacture and Assembly, CRC Press, 2011.
2. James G. Brala, Design for Manufacturability Handbook, McGraw Hill, New York, 1999.
3. O. Molloy, Steven Tilley, E.A. Warman, Design for Manufacturing and Assembly: Concepts, Architectures and Implementations, Springer Books, 1998.
4. C. Poli, Design for Manufacturing- A structured approach, Volume1; Buttworth-Heinneman, Elsevier publications, 2001.

## AAE ****: DIGITAL MANUFACTURING [3 0 0 3]

Introduction: Definition, features and developments of Digital Manufacturing (DM), Basic Concept and Connotation of Digital Manufacturing Science. Modeling Theory and Method of Digital Manufacturing Science: Critical Modeling Theories and Technologies in Digital Manufacturing Science, Basic Architecture Model of Digital Manufacturing System. [7]

Computing Manufacturing in DM: C-Space and Screw Space, Virtual Prototyping. Manufacturing Computational Model, Computational Geometry. Manufacturing informatics in DM: Principal Properties of Manufacturing Information, Measurement, Synthesis and Materialization of, Manufacturing Information Integration, Sharing and Security of Manufacturing Information. [7]

Intelligent manufacturing in DM: Intelligent Multi Information Sensing and Fusion in the Manufacturing Process, Knowledge Engineering in the Whole Life Cycle of Manufacturing Product, Intelligent Manufacturing System. Artificial Intelligence and Intelligent Manufacturing Systems. [7]

Industry 4.0: Artificial Intelligence and intelligent manufacturing systems, smart factories: Levels of smart factories, benefit of smart factories, key principles of smart factories, Industry 4.0 and its components, Transitioning for Industry 3.0 to Industry 4.0. Industrial IoT: IoT in global context, Design Principles, IoT in manufacturing, Cyber Physical systems in manufacturing, M2M technology: Application, key features, architecture and components. [7]

Management of Technology in DM: Concept and development process, R&D System Framework and Management Mode, Human–Machine Engineering on DM Process. Rapid Manufacturing: Introduction and processes, digital Manufacturing security. Future Development of DM: The Precision of Digital Manufacturing, The Externalization of Digital Manufacturing, The Environmental Protection of Digital Manufacturing. [6]

**References:**

1. Zude Zhou, Shane (Shengquan) Xie Dejun Chen, Fundamentals of Digital Manufacturing Science, Springer-Verlag London Limited, 2012.
2. Kaushik Kumar, Divya Zindani, J. Paulo Davim (Editors) Digital Manufacturing and Assembly Systems in Industry 4.0 CRC Press, 2020.
3. Antonella Petrillo, Raffaele Cioffi, Fabio De Felice, Digital Transformation in Smart Manufacturing Intech Publishers Croatia, 2018.
4. Hopkinson N, Hague R. J. M., Dickens P.M. Rapid Manufacturing, John Wiley and sons, 2006.

## AAE ****: EARTH MOVING EQUIPMENT AND FARM MACHINERY [3 0 0 3]

Basic of IC Engine: Introduction to IC engine, Engine Component overview, Lubrication system, Cooling System, Fuel Injection System, Turbocharger, Super charger, After Coolers. [6]

Transmission and Final Drive: Basic types of transmissions, auxiliary transmission, compound transmission, twin triple countershaft transmissions and planetary transmission, constructional and working principles, hydro shift automatic transmission and retarders. Final drives, types of reductions final drives and planetary final drives, PTO shaft. [6]

Steering and Brakes: Power steering types, linkage type power steering, semi integral power steering & integral power steering. Steering of tracked vehicles, Skid steering, articulated steering, clutch /brake steering system, controlled differential steering system and planetary steering system. BRAKES: Types of brakes, disc brake, engine brakes. [5]

Under Carriage and Suspension System: Tyre and tracked vehicles, advantages and disadvantages, under carriage components like, tracks, roller frames, drive sprockets, track rollers, track chains and track shoes. Suspension system, Rubber spring suspension and Air spring suspension. [5]

Earth Moving Equipment's and Operation: Different types of earth moving equipment's and their applications. Construction details and attachments of Dozers, Loaders, Shovels, Excavators, Rippers, Trenchers, Dredgers, Drag Line, Clamshell, Scrapers, Motor Graders, Rollers, Compactors, Types of maintenance schedules purpose and advantages, organization set ups, documentation. Safety methods for earth moving equipment. [10]

Farm Machinery: Tractors, Primary and Secondary Tillage Equipment's, Harvesting Equipment's, Types of Sprayers [4]

**References:**


1. S C Sharma, Construction Equipment and Management, Khanna Publishers, 2013.
2. Newton K and Steeds, Motor Vehicle, W. Butter Worths & Co., Publishers Ltd, 2004.
3. N.K. Giri, Automobile Mechanics, Khanna Publications, New Delhi, 2003.
4. Robert. L. Peurifoy, Clifford J. Schexnayder, A viad Shapira, Construction Planning, Equipment, and Methods, McGrawHill Higher Education, 2006.
5. Harris Pearson Smith, Farm Machinery and Equipment, Tata McGRAW HILL Publishers, 2020.


## AAE ****: ELECTROCHEMICAL ENERGY STORAGE [2 1 0 3]

Introduction to Energy storage and battery terminology: Brief history of electrochemical energy storage, Requirement of energy storage, Definition and measuring methods. [3]

Electrochemistry and Thermodynamics: Electrochemical Cell, Faradays law of electrochemistry, Redox potential, Electromotive force, Nernst's law, Electrical double layer, Polarization and over potential. Heat Generation and Porous media. [6]

Batteries: Types of batteries, Lead Acid, Nickel metal hydride, Nickel-Zinc batteries, Zinc-air and Redox flow batteries. Li-ion batteries: Operational mechanisms of lithium ion batteries, Properties of electrode material, Dendrite formation. [9]

Fuel cells and Super capacitors: Introduction, Types of fuel cells, Proton exchange membrane fuel cell, Alkaline fuel cells, Phosphoric acid fuel cell, Solid oxide fuel cells, Molten carbonate fuel cells, Direct methanol fuel cells. Fundamentals of capacitors, Energy stored, Double layer capacitor, Charging and discharging behaviour of supercapacitors. [9]

Basic elements of in lithium-ion batteries and Fabrication: Introduction, Positive electrodes, Negative electrodes, electrolytes, Current collectors, Manufacturing and packaging. [9]

**References:**


1. Glaize, Christian, and Sylvie Genies. Lithium batteries and other electrochemical storage systems, John Wiley and Sons, 2013.
2. Sundén, Bengt. Hydrogen, Batteries and Fuel Cells, Academic Press, 2019.
3. Sterner, Michael, and Ingo Stadler, eds. Handbook of energy storage: Demand, technologies, integration, Springer, 2019.
4. Newman, John, and Karen E. Thomas-Alyea. Electrochemical systems, John Wiley and Sons, 2012.
5. O'hayre, Ryan, Suk-Won Cha, Whitney Colella, and Fritz B. Prinz. *Fuel cell fundamentals*, John Wiley and Sons, 2016.


## AAE ****: EXPERIMENTAL MECHANICS [2 1 0 3]

Overview of experimental stress analysis, Stress analysis – Analytical, Numerical and Experimental approaches, Specific domain of these approaches, Advantages, and disadvantages [6]

Stress, Strain and Displacement Fields- Beam under pure bending, Analytical solution, Fringe contours from various experimental methods [8]

Physical Principle of Strain Gauges, Photoelasticity, Physical principle behind various experimental techniques, Strain Gauges, Photoelasticity, Grids for determining plastic strains [8]

Multi-Scale Analysis in Experimental Mechanics- Review of solid mechanics, definition of free surface, ambiguity in associating the correct value of principal stress direction to the magnitude of the principal stress [8]

Eigen value approach or use of Mohr's circle, Shear distribution in a three point bend specimen [6]

**References:**


1. Cesar A. Sciammarella, Federico M. Sciammarella, Experimental Mechanics of Solids, John Wiley &Sons, 2012.
2. Emmannuel D Gdoutos, Recent advances in experimental mechanics, Kluwer Academic Publications, 2002.
3. Jerome Molimard, Experimental Mechanics of Solids and Structures, ISTE, John Wiley & Sons, 2016.
4. Rivka Gilat, Leslie Bank-Sills, Advances in Mathematical Modelling and Experimental Methods for Materials and Structures, Springer Science, 2010.


## AAE ****: HUMAN FACTORS IN AUTOMOTIVE ENGINEERING [3 0 0 3]

Overview of automotive ergonomics and human factor: ergonomics and human factor compatibility, vehicle cabin design, instrument displays, riding comfort and fatigue, vehicle interior environment, driver task and non-driving task, driving behaviour measurement, automated assistance systems, future of automobile ergonomics [8]

Ergonomics and human factor in automobile design and development process; responsibility and roles, development process, identifying user requirement, ergonomic design stage, assessment stage, feedback from user, surveys for understanding users in design stage, questioner and interview approach, driving behaviour measurement using simulators, driver behaviour measurement using instrumented vehicles, driving behaviour analysis. [7]

Comfort and quality; occupant comport during vehicle run, comfort of the seat, body movement caused by acceleration, seat support performance, acoustic comfort, cabin air quality, visual environment of vehicle interior, interior materials. [7]

Driver state; driver fatigue, workload and stress, enjoyment generated by automobiles, arousal level and measurement, eye movement, eyelid activity, arousal enhancing technology. [7]

Driver and system interaction; metal workload while using in-vehicle system, HMI of car information system, Design menus, assessment of drivers distraction, interaction with advanced driver assistance system. [7]

**References:**


1. Guy H. Walker, Neville A. Stanton, Paul M. Salmon, Human Factors in Automotive Engineering and Technology, Ashgate publisher, 2015.
2. Motoyuki Akamatsu, Handbook of Automotive Human Factors, Taylor & Francis Group, 2021.
3. Paul M. Salmon, Human Factors Methods and Accident Analysis- Practical Guidance and Case Study Applications, Ashgate publisher, 2020.
4. Jediah R. Clark, Neville A. Stanton, Kirsten Revell, Human-Automation Interaction Design Developing a Vehicle Automation Assistant, CRC Press, 2021.


## AAE ****: INDUSTRIAL AUTOMATION AND ROBOTICS [3 0 0 3]

Introduction to pneumatic systems: Structure and signal flow of pneumatic systems, Compressors, Air generation and distribution, Constructional details and working of filter, lubricator, and pressure regulator, Advantages and limitations, Applications. [6]

Sensors and Actuators: Symbols of pneumatic valves, types of pneumatic actuators traverse time diagram, Design of manually operated circuits, push buttons, rollers, flow, pressure control valves, time delay, counter circuits, control of multiple actuators. [10]

Electronic actuation systems: Electrically actuated direction control valves, Relay control systems, Design of electro pneumatic circuits, Limit switches, magnetic, inductive, capacitive, optical, ultrasonic, pneumatic proximity sensors, introduction to PLC. [10]

Robotics: Introduction to Robotics, Rigid-Body Kinematics, Dynamics of Robots, Trajectory Planning for Flexible Robots, Robotic Sensors, Robot End Effectors, Robot Programming, Industrial Applications. [10]

**References:**

1. Joji P, Pneumatic Controls, Wiley India Pvt. Ltd, 2013.
2. Prede G. and Scholz D., Electropneumatics Basic Level, Festo Didactic GMBH & Co, Germany, 2012.
3. Peter Croser, Frank Ebel, Pneumatics Basic Level TP 101, Festo Didactic GMBH & Co, Germany, 2012.
4. A.K. Gupta, S.K. Arora and J. Riescher Westcott, Industrial Automation and Robotics, Mercury Learning and Information, 2016.
5. Thomas R. Kurfess, Robotics and Automation Handbook, CRC Press, 2004.
6. Martin Klas Nilsson J. Norberto Pires, Industrial Robotics, Springer, 2007.

## AAE ****: LEAN MANUFACTURING [3 0 0 3]

History of Lean and comparison to other methods – The 7 Wastes, their causes and the effects – An overview of Lean Principles / concepts / tools – Stockless Production. [2]

The Tools of Lean Manufacturing: Continuous Flow – Continuous Flow Manufacturing and Standard Work Flow – 5S and Pull Systems (Kanban and ConWIP systems) – Error Proofing and Set-up Reduction – Total Productive Maintenance (TPM) – Kaizen Event examples. Just-in-time manufacturing. Toyota production systems, Ford production systems. [8]

Value Stream Mapping – Future State: Key issues in building the Future State Map – Process tips in building the map and analysis of the customer loop, supplier loop, manufacturing loop and information loop – Example of completed Future State Maps – Application to factory simulation – Implementation of lean practices – Best Practices in Lean Manufacturing. [8]

House of Lean -5S's and Waste Walks, Visual Management, Value Stream Mapping-Understanding the current state and designing the future state Managing lean enterprise: – Finance, Career ladders, geographic spread and advantages of global enterprise. [8]

Additional Interests: Develop VSM Current and Future state diagram using Microsoft Visio or Similar Software Package. [2]

Six sigma concepts: History, definitions, Statistical definitions, quality levels, Technical aspects, Six sigma for all: benefits to organizations, customers, suppliers and employers, Design for Six Sigma, DMAIC principles, DMADV principles, merits and demerits. [8]

**References:**

1. Yasuhiro Monden, Toyota Production System -An integrated approach to Just in Time, Engineering and Management Press -Institute of Industrial Engineers, 1983.
2. James P Womack, Daniel T Jones, and Daniel Roos, The Machine that changed the World. The Story of Lean Production -Harper Perennial edition, 1991.
3. Gemba Kaizen: A Commonsense Approach to a Continuous Improvement Strategy, Second Edition Hardcover, 2012.
4. Karen Martin, Mike Osterling, Value Stream Mapping: How to Visualize Work and Align Leadership for Organizational Transformation Paperback, 2016.
5. Suvabrata Mitra, Lean and Six Sigma – Six Sigma Black Belt Enterprise-Wide Deployment Paper Back, 2007.

## AAE ****: METROLOGY & MEASUREMENTS [3 0 0 3]

Introduction Metrology: Need for Inspection, Accuracy and Precision, Accuracy and Cost, Objectives of Metrology and Measurements General Measurement Concepts Calibration of Measuring Errors in Measurements, Principle of Interchangeability, Standards and their Roles, Material Standard, Wavelength Standard, Line and End Measurements, Calibration of End Bars [6]

Limits, fits & tolerances: Introduction, Selective Assembly Approach, Tolerances, Maximum and Minimum Metal Conditions, Fits, Allowances, Hole Basis and Shaft Basis Systems, System of Limits and Fits, Classification of Gauges, Taylor's Principle, Gauge Tolerance, Types of gauges, Plain gauges, snap gauges. [6]

Metrology of gears: Gear Terminology, Errors in Spur Gears, Measurement of Gear Elements, Screw Thread Terminology, Measurement of Screw Thread Elements. [4]

Direct & indirect measurements: Linear Measurement: Scaled Instruments, Vernier Instruments, Micrometre Instruments, Slip gauges. Angular Measurement: Sine Bar, Angle Gauges, Spirit Level, Optical Instruments for Angular Measurement, Autocollimator. Comparators: Mechanical Comparators, Mechanical–Optical Comparators, Electrical Comparators, Pneumatic Comparators. Optical Measurement Techniques, Optical Interference, Interferometry, Interferometers, NPL Flatness Interferometer, Laser Interferometers. [9]

Digital manufacturing: Introduction, Concepts and Research and Development Status of Digital Manufacturing, Features and Development of Digital Manufacturing, Various Digital Technologies in Product Lifecycle, CAx Technology Integration, Digital Equipment and Digital Processing Technology, The Technology of Digital Maintenance and Diagnosis, Digital Logistic Technology, Resource and Environment Technology in Digital Manufacture, Management Technology in the Digital Manufacturing Process and System, Control Technology in Digital Manufacture, Digital Recognition and Integration Technology in Product, Emerging Rapid Manufacturing Processes. [11]

**References:**


1. Les Kirkup and Bob Frenkel, An Introduction to Uncertainty in Measurement, Cambridge University Press, 2006.
2. Mark A. Curtis and Francis T. Farago, Handbook of Dimensional Measurement, Industrial Press, 2014.
3. David Whitehouse, Surfaces and their measurement, Butterworth-Heinemann, 2004.
4. Gene R. Cogorno, Geometric Dimensioning and Tolerancing for Mechanical Design, McGraw-Hill, 2012.
5. Bryan R. Fischer, Mechanical Tolerance Stack-up and Analysis, CRC Press, 2004.


## AAE ****: NUMERICAL METHODS FOR SCIENTIFIC COMPUTING [3-0-0-3]

Introduction: Background - Representation of Numbers on a Computer - Errors in Numerical Solutions - Round-Off Errors - Truncation Errors - Total Error. [2]

Mathematical Background: Concepts from Pre-Calculus and Calculus – Vectors - Operations with Vectors - Matrices and Linear Algebra - Operations with Matrices - Special Matrices - Inverse of a Matrix - Properties of Matrices - Determinant of a Matrix - Cramer s Rule and Solution of a System of Simultaneous Linear Equations – Norms - Ordinary Differential Equations (ODE) - Functions of Two or More Independent Variables - Definition of the Partial Derivative - Chain Rule - The Jacobian - Taylor Series Expansion of Functions - Taylor Series for a Function of One Variable - Taylor Series for a Function of Two Variables - Inner Product and Orthogonality. [8]

Solving Nonlinear Equations: Estimation of Errors in Numerical Solutions - Bisection Method - Regula Falsi Method - Newton's Method - Secant Method - Fixed-Point Iteration Method - Equations with Multiple Solutions - Systems of Nonlinear Equations - Newton's Method for Solving a System of Nonlinear Equations - Fixed-Point Iteration Method for Solving a System of Nonlinear Equations. [5]

Solving a System of Linear Equations: Overview of Numerical Methods for Solving a System of Linear Algebraic Equations - Gauss Elimination Method - Potential Difficulties When Applying the Gauss Elimination Method - Gauss Elimination with Pivoting - Gauss-Jordan Elimination Method - LU Decomposition Method - LU Decomposition Using the Gauss Elimination Procedure - LU Decomposition Using Crout's Method - LU Decomposition with Pivoting - Inverse of a Matrix - Calculating the Inverse with the LU Decomposition Method - Calculating the Inverse Using the Gauss-Jordan Method - Iterative Methods - Jacobi Iterative Method 133 4. 7. 2 Gauss-Seidel Iterative Method. [6]

Eigenvalues and Eigenvectors: The Characteristic Equation - The Basic Power Method - The Inverse Power Method - The Shifted Power Method - The QR Factorization and Iteration Method. [2]

Numerical Differentiation: Finite Difference Approximation of the Derivative - Finite Difference Formulas Using Taylor Series Expansion - Finite Difference Formulas of First Derivative - Finite Difference Formulas for the Second Derivative - Differentiation Formulas Using Lagrange Polynomials - Differentiation Using Curve Fitting - Richardson's Extrapolation - Error in Numerical Differentiation - Numerical Partial Differentiation. [4]

Numerical Integration: Overview of Approaches in Numerical Integration - Rectangle and Midpoint Methods - Trapezoidal Method - Composite Trapezoidal Method - Simpson's Methods - Simpson's 1/3 Method - Simpson's 3/8 Method - Gauss Quadrature - Evaluation of Multiple Integrals - Estimation of Error in Numerical Integration - Richardson's Extrapolation - Romberg Integration - Improper Integrals. [4]

Ordinary Differential Equations: Euler's Methods - Eulers Explicit Method - Analysis of Truncation Error in Euler s Explicit Method - Eulers Implicit Method - Modified Euler's Method - Midpoint Method - Runge-Kutta Methods - Second-Order Runge-Kutta Methods - Third-Order Runge-Kutta Methods - Fourth-Order Runge-Kutta Methods - The Shooting Method - Finite Difference Method - Error and Stability in Numerical Solution of Boundary Value Problems. [5]

**References:**


1. John A. Trangenstein, 'Scientific Computing - Vol I, II, III, Springer, 2010.
2. Parviz Moin, Fundamentals of Engineering Numerical Analysis, Cambridge, 2010.
3. Steven C. Chapra, Applied Numerical Methods, McGraw Hill, 2012.
4. Walter Gander, Martin J. Gander, Felix Kwok, Scientific Computing, Springer, 2010.
5. A.S. Ackleh, E.J. Allen, R.B. Hearfott, P. Seshiyer, Modern Numerical Analysis, CRC, 2009.
6. Amos Gilat, Vish Subramaniam, Numerical Methods for Engineers and Scientists, Wiley, 2014.


## AAE ****: OPERATIONS RESEARCH [3 0 0 3]

Introduction: Origin and development, Feature or OR, Methodology of OR, Linear Programming Model: Formulation of real life situations Solutions methodology: Graphical method, simplex method. Special cases:- Unbounded, In-feasible, Alternate and degenerate solution Two phase method. Duality Theory Dual simplex method Post Optimal Analysis. [10]

Transportation Model: Formulation Transportation algorithm Developing initial BFS using North West corner Rule, Least cost cell method, VAM, Row/Column Minimum Method Testing the solution and improving using stepping stone method and MODI method. Resolving unbalance, degeneracy. [6]

Assignment Model: Formulation, Hungarian Algorithm Tackling Unbalance. [3]

Game Theory: Two person Zero Sum game Formulation Pure strategy and Mixed strategy Solution methodology: Graphical method and LP method. [4]

Dynamic Programming: Decomposition stages, Recursive equations, Deterministic Discrete state DP applications. [4]

Network Models Shortest path problem: Minimum spanning tree problem, Maximum flow problem Project Management with PERT/CPM Network construction Scheduling with CPM/PERT. Time cost trade-off. [6]

Queuing Theory: General structure of system. Analysis of M/M/1 with infinite and finite population, self service system. [3]

**References:**


1. Vohra N.D.: Quantitative Techniques in Management, Tata McGraw Hill Publishing co. Ltd., New Delhi, 2017.
2. Hamdy Taha, Operation Research, an Introduction, Pearson, 2016.
3. Hiller, Liberman, Introduction to Operations Research, McGraw HIll International, 2017.
4. Gillet B.E, Operations Research Tata McGraw Hill, 2000.
5. Gupta, Hira, Operations Research S. Chand & Co., 2018.
6. Don T. Phillips, A. Ravindran And James J. Solberg, Operations research: principles and practice Wiley, 2007.


## AAE ****: OPTIMIZATION TECHNIQUES IN ENGINEERING [3-0-0-3]

Introduction: Optimal Problem Formulation - Design Variables – Constraints - Objective Function - Variable Bounds - Engineering Optimization Problems - Classification of Optimization Algorithms. [4]

Single-variable Optimization Algorithms: 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 - Root-finding Using Optimization Techniques. [12]

Multivariable Optimization Algorithms: Optimality Criteria - Unidirectional Search - Direct Search Methods - Hooke-Jeeves Pattern Search Method - Powell's Conjugate Direction Method - Gradient-based Methods - Cauchy's (Steepest Descent) Method - Newton's Method - Conjugate Gradient Method. [6]

Constrained Optimization Algorithms: Kuhn-Tucker Conditions - Lagrangian Duality Theory - Penalty Function Method - Method of Multipliers - Feasible Direction Method - Quadratic Programming - Sequential Quadratic Programming. [4]

Non-traditional Optimization Algorithms: Genetic Algorithms - Working Principles - Differences between GAs and Traditional Methods - Similarities between GAs and Traditional Methods - GAs for Constrained Optimization - Other GA Operators - Real-coded Gas - Multi-objective Gas - Simulated Annealing - Global Optimization - Using the Steepest Descent Method - Using Genetic Algorithms - Using Simulated Annealing. [10]

**References:**


1. Ravindran, A., Phillips, D. T., and Solberg, J. J., Operations Research: Principles and Practice, Wiley-India, 2006.
2. Rao, S. S., Engineering Optimization: Theory and Practices, John Wiley, 2009.
3. Winston, W. L., Operations Research: Applications and Algorithms, Cengage Learning, 2010.
4. Ravindran, A., Ragsdell, K. M., and Reklaitis, G. V., Engineering Optimization: Methods and Applications, Wiley-India, 2006.
5. Deb, K., Optimization for Engineering Design: Algorithms and Examples, PHI Learning, 2012.
6. Deb, K., Multi-Objective Optimization Using Evolutionary Algorithms, Wiley-India, 2010.


## AAE ****: STATISTICAL QUALITY CONTROL AND RELIABILITY [3 0 0 3]

Introduction: Definitions of the term quality, Functions of Inspection and Quality Control. Introduction to Total Quality Control, Organization for quality, General quality control engineering fundamentals: Measures of central tendency and dispersion like Average, Standard deviation, Median, Mode, Range, Variance, Concept of variation, Causes of Variation, Patterns of variation, Frequency distribution, The Normal distribution curve, Tchebyeheff's and Camp-Meidell's Inequality theorems. Shewhart's bowl drawing experiments. [5]

Modeling Process Quality: Probabbilistic relationships, Descrete and continuous proability distributions. Tolerance allocation when the means are not equal to the nominal sizes. Tolerance Allocation when the Number of Processes is Finite [4]

Methods of Statistical Process Control and Capability Analysis: $\bar{X}$ ,R & s charts, Type I and Type II Errors. Process capability analysis Process capability indexes – Cp and Cpk. Control charts for attributes: p, np, c and u charts [12]

Acceptance sampling: Acceptance sampling by attributes – Single, Double and Multiple sampling plans, Operating characteristic curve, AOQ curve, AOQL, Average Total Inspection, Average Fraction Inspected, ASN curve. Producer's and Consumer's risks, Dodge-Roming & MIL-STD acceptance sampling tables. [9]

Reliability Engineering: Concepts of reliability, Statistical Models of reliability, Reliability of hazard functions, System reliability, Redundancy techniques in system design. Failure modes, effects & criticality analysis, Fault tree analysis, Event tree analysis Design review & validation, Design for reliability [6]

**References:**


1. Montgomery D. C., Introduction to Statistical Quality Control, John Wiley & Sons, New York, 2013.
2. Amitav Mitra, Fundamentals of quality control and improvement, Wiley, 2008.
3. Grant E.L., Statistical Quality Control, McGraw Hill Publications, New York, 1988.
4. Juran J.M., Quality Planning and Analysis, McGraw Hill Publications, Delhi, 1984.
5. Rao S S., Reliability Engineering Pearson Education, 2014.


## AAE ****: SURROGATES AND APPROXIMATIONS IN ENGINEERING DESIGN [2 1 0 3]

Sampling Plans: The 'Curse of Dimensionality' and How to Avoid It - Physical versus Computational Experiments - Designing Preliminary Experiments (Screening) - Estimating the Distribution of Elementary Effects - Designing a Sampling Plan – Stratification - Latin Squares and Random Latin Hypercubes - Space-filling Latin Hypercubes - Space-filling Subsets. [10]

Constructing a Surrogate:The Modelling Process - Stage One: Preparing the Data and Choosing a Modelling Approach - Stage Two: Parameter Estimation and Training - Stage Three: Model Testing - Polynomial Models - Radial Basis Function Models - Fitting Noise-Free Data - Radial Basis Function Models of Noisy Data – Kriging - Building the Kriging Model - Kriging Prediction - Support Vector Regression - The Support Vector Predictor - The Kernel Trick - Finding the Support Vectors. [16]

Exploring and Exploiting a Surrogate: Searching the Surrogate - Infill Criteria – Prediction-Based Exploitation – Error-Based Exploration - Balanced Exploitation and Exploration - Conditional Likelihood Approaches - Other Methods. [10]

**References:**

1. Forrester, A., & Keane, A., Engineering design via surrogate modelling: a practical guide. John Wiley & Sons, 2008.
2. Jiang, P., Zhou, Q., & Shao, X., Surrogate model-based engineering design and optimization. Springer, 2020.

## AAE ****: TOTAL QUALITY MANAGEMENT [3 0 03]

Introduction to TQM: Introduction-Definition, Basic Approach, and Contribution of Gurus-TQM framework, Historical Review, Benefits of TQM, TQM organization. Leadership, Customer Satisfaction and Employee Involvement: Characteristics of quality leaders, Customers satisfaction, Customer perception of quality, Feedback, Using customer's complaints, Employee involvement-Introduction, Teams, Cross functional teams, Quality circles, Suggestion system, Benefits of employee involvement. [7]

Principles and philosophies of quality management: Overview of the contributions of Deming, Juran Crosby, Masaaki Imai, Feigenbaum, Ishikawa, Taguchi techniques – introduction, loss function, parameter and tolerance design, signal to noise ratio. Concepts of Quality circle, Japanese 5S principles and 8D methodology. [4]

Continuous Process Improvement and Tools Techniques: The Juran trilogy, improvement strategies, types of problems, the PDSA Cycle, problem-solving methods, Kaizen, reengineering, six sigma, case studies. Statistical Process Control: Pareto diagram, process flow diagram, cause and effect diagram, check sheets, histograms, statistical fundamentals, Control charts, state of control, out of control process, control charts for variables, control charts for attributes, scatter diagrams, case studies. [8]

Meaning and significance of statistical process control (SPC) – construction of control charts for variables and attributed. Process capability – meaning, significance and measurement – Six sigma concepts of process capability. Reliability concepts – definitions, reliability in series and parallel, product life characteristics curve. Total productive maintenance (TMP) – relevance to TQM, Terotechnology. Business process re-engineering (BPR) – principles, Applications, reengineering process, benefits and limitations. [9]

Quality functions development (QFD) – Benefits, Voice of customer, information organization, House of quality (HOQ), building a HOQ, QFD process. Failure mode effect analysis (FMEA) – requirements of reliability, failure rate, FMEA stages, design, process and documentation. Statistical tools, Management tools. Bench marking and POKA YOKE. [8]

**References:**

1. John L. W. Beckford, Quality: A Critical Introduction, Routledge Taylor and Frances Group, New York and London, 2016.
2. Dale H. Besterfield, Carol Besterfield - Michna, Glen H Besterfield and Mary Besterfield-Sacre, Total Quality Management, PHI, 2006.
3. Ron Basu, Implementing Quality: A Practical Guide to Tools and Techniques, THOMPSON, 2006.
4. Greg Brue, Six Sigma for Managers, TMH, 2002.
5. R. P. Mohanty & R. R. Lakhe, TQM in the Service Sector, Jaico Books, 2001.

## AAE ****: TYRE TECHNOLOGY [3 0 0 3]

Introduction to Tire Engineering: Introduction to the Global Tire Industry, Tire Technology, Tire Construction, Mission Profile and Design Envelopes, Dimensions and Nomenclature, Tire Speed and Load Rating, Trends in Tire Sizes, Secondary Factors Influencing Tire Design, Off-Road Tires, Farm Tires, Aircraft Tires, Tire Material Composition [3]

Tire Tread Technology: Introduction Tread Compounds, Radial Tire Tread Design Parameters, Tire Footprint Pressure, Tread Extrusion Contour, Tread Radius, Tread Wear Mechanisms, Tire Casing Construction: Introduction to Casing Components, Belt Design, Casing Construction, Inner Liner and Barrier, Ply, Sidewall, Bead, Apex (Bead Filler), Chafer (Toe Guard), Shoulder Wedge, Model Compound Line-up [4]

Tire Innerliner: Introduction to Production of Bromobutyl Rubber, Tire Inner liner, Tire Inflation Pressure Loss Rate (IPLR), Tire Intra-carcass Pressure (ICP), Tire Inner liner Compound Properties, Inner liner and Tire Manufacturing, Nitrogen Inflation and New Technologies, Vulcanization of Halobutyl Tire Inner liner Compounds. [6]

Tire Reinforcements: Introduction, Fabric Tire Cords, Cord Construction, Fabric Production, Cord-to-Rubber Compound Adhesive, Steel Cord, Mechanism of Brass-Coated Steel Wire-to-Rubber, Adhesion Bead Wire [2]

Radial Tire Materials Technology and Rubber Compounding: Introduction, Polymers Used in Tires, Production of Natural Rubber, Natural Rubber Products and Grades, TSR-L, TSR-5, TSR-10, TSR-20, TSR-50, Quality, Properties of Natural Rubber Compounds, Synthetic Elastomers Used in Tires, Carbon Black and its Properties, Silica, Silicates, and Other Inorganic Fillers, Protectant Systems, Vulcanization Systems, Tire Factory Compound Processing Aids, Compound Production Efficiencies. [4]

Radial Tire Compound Polymer Blends: Introduction to applied Polymer Technology, Tire Components, Blending Elastomers, Processing of Elastomer Blends, Natural Rubber–Bromobutyl Blends, Halobutyl–Butyl Blends, Bromobutyl–GPR Blends, Distribution of Compounding Ingredients: Insoluble Chemicals, Distribution of Compounding Ingredients: Soluble Chemicals, Effect of Blending on Compound Physical Properties, Secondary Polymer Blends Systems, Tackifying Resins, Reinforcing Resins, Curing Resins, Polymeric Green Strength Promoter, Elastomer Blends and Tire Performance. [6]

Tire Manufacturing: Introduction, Raw Materials Receiving and Compound Mixing, Component Preparation, Electron Beam Radiation Processing, Tire Building, Tire Curing (Vulcanization), Final Finish, Shipping, Tire Production and the Environment. [2]

Manufacturing Quality Control and Tire Uniformity: Introduction, Raw Materials and Compound Mixing, Component Preparation, Tire Building, Tire Curing, Final Finish, Tire Uniformity, Fundamental Tire Forces, Radial Force Variation, Aligning Torque and Steering Moment, Overturning Moment (Mx), Radial Force Variation (Fz), Radial Run-out, Lateral Force Variation, Conicity, Ply Steer, Lateral Run-out, Harmonic Waveform Analysis, Grinding, Global Quality Management Standards. [4]

Tire Testing and Performance: Introduction to Laboratory Testing, FMVSS139 Tests, Endurance, Low Inflation Pressure Performance, The High-Speed Test, Description of Potential Tire Removal Modes, Rolling Resistance, Bead Area Durability, Inflation Pressure Retention, Tire Proving Grounds, Traction Testing, Noise, Tread Wear, Tire Vehicle Handling, Commercial Fleet Programs, Truck Fuel Consumption, Commercial Fleet Tire Wear. [5]

**References:**


1. Brendan Rodgers, Tire engineering – An introduction, CRC Press, 2020.
2. Bireswar Banerjee, Tyre Retreading, Walter de Gruyter Publishers, 2019.
3. Saikat Das Gupta, Rabindra Mukhopadhyay, Krishna C. Baranwal, Anil K. Bhowmick, Reverse Engineering of Rubber Products Concepts, Tools, and Techniques, Taylor & Francis, 2013.
4. Hans B. Pacejka, Tire and Vehicle Dynamics, Third Edition, Butterworth-Heinemann, 2012.
5. M. S. Evans,Tyre Compounding for Improved Performance, iSmithers Rapra Publishing - Science, 2002.


## AAE ****: VEHICLE EMBEDDED SYSTEMS [3 0 0 3]

Embedded Systems: Understanding the Basic Concepts, Introduction to Embedded Systems, The Typical Embedded System, Embedded Systems—Application- and Domain-Specific, Designing Embedded Systems with Microcontrollers, Programming and Embedded Hardware Design and Development [6]

**Design and Development of Embedded Product**, Embedded Firmware Design and Development, Real-Time Operating System (RTOS) based Embedded System Design. Integration and Testing of Embedded Hardware and Firmware, The Embedded System Development Environment, Product Enclosure Design and Development, The Embedded Product Development Life Cycle (EDLC). [6]

**Firmware Design and Development**-Tools, EDA, OrCAD, PCB, embedded firmware development languages, IDE, ECU and ECU, IDE, Development Tools, Software Development Tools. [5]

**Automotive Grade Microcontrollers**, Safety Critical Microcontrollers, Microcontrollers with Built in CAN Interface, Automotive Embedded System Design, Advanced Trends in Automotive Electronics. [4]

**Automotive Architectures**: Vehicle Functional Domains and Their Requirements, Application of the AUTOSAR Standard, Intelligent Vehicle Technologies. [5]

**Embedded Communications**: Product Lines in Automotive Electronics, Reuse of Software in Automotive Electronics, Automotive Architecture Description Languages, Model-Based Development of Automotive Embedded Systems. [5]

**Verification and Validation**: V & V process, Softwares Tools, Types of Test and standards and diagnostic interface etc. Testing Automotive Control Software, Testing and Monitoring of FlexRay-Based Applications,

Timing Analysis of CAN-Based Automotive Communication Systems, Controller Area Network, Formal Methods. [5]

**References:**


1. K.V. Shibu, Introduction to Embedded Systems, McGraw Hill Education India Private Limited, 2017.
2. Nicolas Navet (Editor) and Francoise Simonot-Lion (Editor), Automotive Embedded Systems Handbook (First Edition) (Industrial Information Technology), CRC Press, 2009.
3. John F. Kershaw, Ed.D. and James D. Halderman, Automotive Electrical and Electronic Systems, Pearson Education, 2007.
4. Edward A. Lee and Sanjit A. Seshia, Introduction to Embedded Systems, A Cyber-Physical Systems Approach, MIT Press, ISBN 978-0-262-53381-2, 2017.
5. Eric Armengaud, Allan Tengg et al, Automotive Embedded Systems, Springer, 2011.
6. Wilfried Voss, A Comprehensible Guide to Controller Area Network, Copperhill Media Corporation, 2005.


## OPEN ELETIVES

### AAE ****: ALTERNATIVES FUELS FOR SUSTAINABLE ENVIRONMENT [2 1 0 3]

Introduction: Introduction, Energy security, Environmental pollution, Need for alternate fuels. [2]

Methanol: Methanol Production, Properties of methanol, Methanol and Gasoline blend, Combustion and Emission Characteristics in engine. [4]

Vegetable oils: properties, Methods to use in engines, performance and emission studies. [3]

Natural Gas, LPG: LPG and CNG Properties, LPG conversion systems required to use in engines – performance in SI & CI engines. Merits and Demerits of LPG, advantages and challenges of CNG. [9]

Hydrogen: Energy Carrier, Hydrogen Production, Hydrogen Properties, Hydrogen in Fuel Cells Different types of hydrogen fuel cell, Hydrogen storage. [9]

Electric vehicles: Introduction, principle of electric Vehicle, Construction of Electric Vehicles, Charging of Electric Vehicle Batteries, Vehicle Tests. [9]

**References:**


1. Ramadhas, Arumugam S, Alternative fuels for transportation, Taylor and Francis, 2011.
2. Hordeski, Michael Frank, Alternative fuels: the future of hydrogen, CRC Press, 2020.
3. Richard, L, Alternative Fuels Guidebook Properties, Storage, Dispensing and Vehicle Facility Modifications, Society of Automotive Engineers (SAE), 1997.
4. Singh, Akhilendra Pratap, Alternative Fuels and Their Utilization Strategies in Internal Combustion Engines, Springer Singapore, 2020.
5. Karim, Zainal Ambri Abdul, and Shaharin Anwar Bin Sulaiman, eds. Alternative Fuels for Compression Ignition Engines, Springer, 2018.


### AAE ****: INTRODUCTION TO AUTOMOBILE ENGINEERING [3 0 0 3]

Automotive Engine classification, Engine parts, Introduction to various automotive systems, Fuel supply system, Carburettor, types. Ignition system, battery system, Factors related to cooling system, types of cooling system, Water cooling and air cooling system, Lubrication and types of lubrication system. [12]

Introduction to clutch and classification, Cone, single plate clutch design, Multiplate, Centrifugal, Electromagnetic clutch, Gear box, power flow pattern, Gear ratio, Sliding mesh, constant mesh gear box, Epicyclic transmission, transfer case. [8]

Torque convertor and fluid coupling, Propeller shaft, Differential, Steering mechanism parts, types, Rigid axle steering system, Different types of steering mechanism. [8]

Introduction to Suspension system, leaf springs, Independent suspension system, Introduction to safety systems, brakes, braking efficiency, Types of brakes, Mechanical brakes, disc brakes, Hydraulic, air braking system, Servo braking system, ABS, modern safety aspects, Electrical circuit of vehicle, Starting and lighting system, Types of tyres & wheels and construction. [8]

**References:**

1. Dr Kirpal Singh, Automobile Engineering Vol 1 and Vol 2, Standard Publishers Distributors, 2016.
2. M L Mathur and R P Sharma, Internal Combustion Engines, Dhanpat Rai Publications, New Delhi, 2011.
3. V Ganesan, Internal Combustion Engines, Tata Mcgraw-hill Education, New Delhi, 2012.