

# **Ph. D (Mechanical Engineering)**

**Course Work: Curriculum and Syllabi**

**2022 - 2023**

**Department of Mechanical Engineering**

**Faculty of Engineering**



**KARPAGAM ACADEMY OF HIGHER EDUCATION**

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**(Established Under Section 3 of UGC Act, 1956)**

**(Accredited with A+ Grade by NAAC in the Second Cycle)**

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## FACULTY OF ENGINEERING DEPARTMENT OF MECHANICAL ENGINEERING

### Ph.D. Course Work Subjects (Effective from the academic year 2022-2023)

Paper No.	Course Code	Course Name	Credit	ESE	Total Marks	Page No.
Paper I	22RME101	Research Methodology and Pedagogy	4	100	100	01
Paper II	22RME201	Research and Publication Ethics	4	100	100	03
Paper III	22RME301	Tribology in Design	4	100	100	05
	22RME302	Advanced Manufacturing Processes	4	100	100	07
	22RME303	Physics of Solar Engineering	4	100	100	08
	22RME304	Advanced Heat and Mass Transfer	4	100	100	10
	22RME305	Industrial Robotics and Expert Systems	4	100	100	12
	22RME306	Refrigeration Systems Design	4	100	100	14
	22RME307	Composite and Polymer Materials	4	100	100	15
	22RME308	Advances in Casting and Welding Processes	4	100	100	17
	22RME309	Supply Chain Management	4	100	100	19
	22RME310	Engineering Metallurgy	4	100	100	21
	22RME311	Smart Manufacturing	4	100	100	22
	22RME312	Intelligent Industrial Automation and Its Application	4	100	100	24
	22RME313	Alternative Fuels for IC Engines	4	100	100	26
	22RME314	Energy Conservation and Management	4	100	100	27
	22RME315	Fuel Cell Technology	4	100	100	28
	22RME316	Micro-Machining and Precision Engineering	4	100	100	29
	22RME317	Optimization Techniques	4	100	100	31
22RME318	Computational Methods	4	100	100	33	
22RME319	Finite Element Analysis	4	100	100	35	

## Ph.D. COURSE WORK SYLLABUS

### MECHANICAL ENGINEERING

#### RESEARCH METHODOLOGY AND PEDAGOGY (Effective from the academic year 2022-2023 onwards)

CODE: 22RME101

#### UNIT I

##### INTRODUCTION TO RESEARCH

Research Methodology: An Introduction –Meaning of research—Objectives of Research–Motivation in Research—Types of Research. -Concept of Applied and Basic research – Quantitative and Qualitative Research Techniques – Need for theoretical frame work – Hypothesis development – Hypothesis testing with quantitative data. Research design – Purpose of the study: Exploratory, Descriptive, Hypothesis Testing. Impact Factor--Citation and Citation Index.

#### UNIT II

##### EXPERIMENTAL DESIGN

Laboratory and the Field Experiment – Internal and External Validity – Factors affecting Internal validity. Measurement of variables – Scales and measurements of variables. Developing scales – Rating scale and attitudinal scales – Validity testing of scales – Reliability concept in scales being developed – Stability Measures.

#### UNIT III

##### DATA COLLECTION, ANALYSIS AND INFERENCE

Binomial, Poisson, Normal, Exponential, Weibull and Geometric Distributions. Random sampling, stratified sampling, systematic sampling and cluster sampling. Student–t-test, F-test and  $\chi^2$  test and their applications in research studies. Forecasting methods. Factor analysis, Cluster Analysis and Discriminant Analysis (Basic ideas only). Completely Randomized Design Randomized Block Design and Latin Square Design. Accuracy, Precision and error analysis.

#### UNIT IV

##### MULTIVARIATE STATISTICAL TECHNIQUES

Data Analysis – Factor Analysis – Cluster Analysis – Discriminant Analysis – Multiple Regression and Correlation – Canonical Correlation – Application of Statistical (SPSS) Software Package in Research.

#### UNIT V

##### RESEARCH REPORT AND ETHICS IN RESEARCH

Significance of Report Writing- different steps in report writing–Layout of Research Report—Types of Reports-- Integral parts of a report – Precautions for writing a research report—Oral Presentation. Policy on academic Honesty and Integrity—academic cheating and Plagiarism. Opportunities to carry out research projects with funding/assistance from government agencies.



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## SUGGESTED BOOKS:

1. Donald R. Cooper and Ramela S. Schindler, "Business Research Methods", Tata McGraw-Hill, Publishing Company Limited, New Delhi, 2000.
2. Uma Sekaran, "Research Methods for Business", John Wiley and Sons Inc., New York, 2000.
3. C.K.Kothari, "Research Methodology, methods and techniques", New Age International, New Delhi, 2001.
4. Donald H.McBurney, "Research Methods", Thomson Asia Pvt. Ltd. Singapore, 2002.
5. G.W.Ticehurst and A.J.Veal, "Business Research Methods", Longman, 1999.
6. Ranjit Kumar, "Research Methodology", Sage Publications, London, New Delhi, 1999.
7. Garg, B.L.Karadia, R.Agarwal, & F.Agarwal, U.K. 2002. "An Introduction to Research Methodology", RBSA Publishers.
8. Panneerselvan.R., "Research Methodology", Prentice hall of India, New Delhi, 2004.
9. Ganesan R, "Research Methodology for Engineers", MJP Publishers, Chennai. 2011
10. Walpole R.A, Myers R.H, Myers S.L. and Ye King: "Probability & Statistics for Engineers and Scientists", Pearson Prentice Hall, Pearson Education, Inc. 2007.
11. Graziano, A.M.and Raulin, M.,L.: "Research Methods – A Process of Inquiry", Sixth Edition, Pearson, 2007.
12. Leedy, P.D."Practical Research – Planning and Design", Eighth Edition, Pearson.2005.

## RESEARCH PUBLICATION AND ETHICS

(Effective from the academic year 2022-2023 onwards)

CODE: 22RME201

### UNIT I: PHILOSOPHY AND ETHICS

Introduction to Philosophy: Definition, nature and scope, concept, branches- Ethics: Definition, moral Philosophy, nature of moral judgments and reactions.

### UNIT II: SCIENTIFIC CONDUCT

Ethics with respect to science and research – Intellectual honesty and research integrity – scientific misconduct: Falsification – Fabrication and plagiarism (FFP) – Redundant Publications: duplicate and overlapping publications – salami slicing – Selective reporting and misrepresentation of date.

### UNIT III: PUBLICATION ETHICS

Publication Ethics: Definition, introduction and importance – Best practices / standards setting initiatives and guidelines : COPE , WAME, etc,-Conflicts of interest -Publication Misconduct: definition, concept, problems that lead to unethical behavior and vice versa, type-Violation of publication ethics,

Authorship and contributorship – Identification of publication misconduct, complaints and appeals- Predatory publishers and journals

### UNIT IV: PUBLICATION MISCONDUCT

Group Discussions: Subject specific ethical issues, FFP, authorship- Conflicts of interest- Complaints and appeals: examples and Fraud from India and abroad.

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

### UNIT V: DATABASE AND RESEARCH METRICS

Database : Indexing database-Citation database: Web of Science, Scopus, etc

Research Metrics: Impact Factor of journal as per journal citation Report, SNP, SJR,IPP, Cite score- Metrics:h-index, 110 index, altmetrics.

### UNIT VI: DEVELOPMENT OF E-CONDUCT & IPR

Integrated Library Management System (ILMS) : e-journals-e-books- e- shodhshodhganga- Database –e-content Development –Learning Management system(LMS) –e-PG-Pathshala-CEC(UG) SWAYAM-MOOCs-NPTEL-NMEICT.

IPR: Patent-Copyrights-Trademark-Geographical Indication.



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## PRACTICE

### Open ACCESS Publishing

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

## SUGESSTED READINGS

1. Best Practice Guidelines on Publishing Ethics: A Publisher's Perspective, Second Edition, 2014 John Wiley & Sons, Ltd.
2. Wager E. The Committee on Publication Ethics (COPE): Objectives and achievements 1997- 2012. Presse Med. 2012.
3. Carlson RV, Boyd KM, Webb DJ. The revision of the Declaration of Helsinki: Past, present and future. Br J Clin Pharmacol. 2004.
4. Kambadur Muralidhar, Amit Ghosh,& Ashok Kumar Singhvi "ETHICS in Science Education,Research and Governance",
5. Indian National Science Academy, New Delhi 2019.
6. Publishing Ethics: Academic Research, Cambridge University Press ,Version 2.0, May 2019.



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## TRIBOLOGY IN DESIGN

(Effective from the academic year 2022-2023 onwards)

CODE: 22RME301

### UNIT I

#### SURFACE INTERACTION AND FRICTION

Topography of Surfaces – Surface features-Properties and measurement – Surface interaction – Adhesive Theory of Sliding Friction –Rolling Friction-Friction properties of metallic and non-metallic materials – friction in extreme conditions –Thermal considerations in sliding contact

### UNIT II

#### WEAR AND SURFACE TREATMENT

Types of wear – Mechanism of various types of wear – Laws of wear –Theoretical wear models- Wear of Metals and Non metals – Surface treatments – Surface modifications – surface coatings methods- Surface Topography measurements –Laser methods – instrumentation - International standards in friction and wear measurements

### UNIT III

#### LUBRICANTS AND LUBRICATION REGIMES

Lubricants and their physical properties- Viscosity and other properties of oils –Additives-and selection of Lubricants- Lubricants standards ISO, SAE, AGMA, BIS standards – Lubrication Regimes –Solid Lubrication-Dry and marginally lubricated contacts- Boundary Lubrication- Hydrodynamic lubrication — Elasto and plasto hydrodynamic - Magneto hydrodynamic lubrication – Hydro static lubrication – Gas lubrication.

### UNIT IV

#### THEORY OF HYDRODYNAMIC AND HYDROSTATIC LUBRICATION

Reynolds Equation, -Assumptions and limitations-One and two-dimensional Reynolds Equation- Reynolds and Sommerfeld boundary conditions- Pressure wave, flow, load capacity and friction calculations in Hydrodynamic bearings-Long and short bearings-Pad bearings and Journal bearings-Squeeze film effects-Thermal considerations-Hydrostatic lubrication of Pad bearing-Pressure, flow, load and friction calculations-Stiffness considerations- Various types of flow restrictors in hydrostatic bearings

### UNIT V

#### HIGH PRESSURE CONTACTS AND ELASTO HYDRODYNAMIC LUBRICATION

Rolling contacts of Elastic solids- contact stresses – Hertzian stress equation- Spherical and cylindrical contacts-Contact Fatigue life- Oil film effects- Elasto Hydrodynamic lubrication theory-Soft and hard EHL-Reynolds equation for elasto hydrodynamic lubrication- - Film shape within and outside contact zones-Film thickness and friction calculation- Rolling bearings- stresses and deflections-Traction drives



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## SUGGESTED BOOKS:

1. Rabinowicz.E, “Friction and Wear of materials”, John Willey & Sons ,UK,1995
2. Cameron A. “Basic Lubrication Theory”, Ellis Herward Ltd., UK, 1981
3. Halling J. (Editor) – “Principles of Tribology “, Macmillian – 1984.
4. Williams J.A. “Engineering Tribology”, Oxford Univ. Press, 1994.
5. S.K.Basu, S.N.Sengupta & B.B.Ahuja ,“Fundamentals of Tribology”, Prentice –Hall of India Pvt Ltd , New Delhi, 2005.
6. G.W.Stachowiak& A.W .Batchelor , “Engineering Tribology”, Butterworth - Heinemann, UK,2005.





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## **ADVANCED MANUFACTURING PROCESSES** (Effective from the academic year 2022-2023 onwards)

**CODE: 22RME302**

### **UNIT I**

#### **NEW MACHINING PROCESSES**

(Non thermal energy) – Abrasive machining – water jet machining - ultrasonic machining – chemical machining – electro chemical machining – construction working principle – steps - types – process parameters – derivations – problems, merits, demerits and applications.

### **UNIT II**

#### **NEWER MACHINING PROCESS**

Wire cut EDM - Electro chemical machining – ECG - Electric discharge machining – construction – principle – types – control - circuits – tool design – merits, demerits & applications.

### **UNIT III**

#### **NEWER MACHINING PROCESS**

Laser beam machining – Electron beam machining – Plasma arc machining – Ion beam machining – construction working principle types – process parameter – derivations – problems, merits, demerits and applications.

### **UNIT IV**

#### **FABRICATION OF MICRO DEVICES**

Semiconductors – films and film depurification – Oxidation - diffusion – ion implantation – etching – metallization – bonding – surface and bulk machining – LIGA Process – Solid free form fabrication.

### **UNIT V**

#### **MICROFABRICATION TECHNOLOGY**

Wafer preparation – monolithic processing – moulding – PCB board hybrid & mcm technology – programmable devices & ASIC – electronic material and processing. – steriolithography SAW devices, Surface Mount Technology.

### **SUGGESTED BOOKS:**

1. Serope kelpkijian & Stevan R. Schmid- “Manufacturing process and Engineering materials” – 2003
2. “Micro sensors Mems & smart devices”- Julian W.Hardner – 2002
3. Brahem T. Smith, “Advanced machining”, I.F.S. UK 1989.
4. Jaeger R.C., “Introduction to microelectronic fabrication”, Addison Wesley, 1988.
5. Nario Taniguchi – “Nano technology” – Oxford University Press 1996.
6. Pandey P.C. & Shan HS, “Modern Machining Processes”, Standard Publishing Co., 1980
7. More Madon, “Fundamentals of Micro fabrication”, CRC Press, 1997



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## PHYSICS OF SOLAR ENGINEERING

(Effective from the academic year 2022-2023 onwards)

### UNIT I

CODE:22RME303

#### INTRODUCTION

Basics of solar energy - Brief History of solar energy utilization - Various approaches of utilizing solar energy - Blackbody radiation- Relation between radiation field energy density and radiation spectrum - Planck's formula in energy unit - Maximum spectral density - Planck's formula in wavelength unit - Wien displacement law - Stefan - Boltzmann law - Photoelectric effect - Einstein's theory of photons - Einstein's derivation of the black-body formula.

### UNIT II

#### ORIGIN OF SOLAR ENERGY, TRACKING SUNLIGHT & ATMOSPHERIC INTERACTION

Basic parameters of the Sun - Measurement of the solar constant - The structure of the Sun - The origin of solar energy - Rotation and orbital motion of the Earth around the Sun - Solar time, sidereal time, universal standard time, local standard time - Equation of time - Intensity of sunlight on an arbitrary surface at any time - Interaction with the atmosphere - Absorption of the molecules - Air mass - Rayleigh scattering - Direct and scattered sunlight.

### UNIT III

#### SOLAR CELLS

Formation of a pn - junction - Space charge and internal field - Quasi - Fermi levels - The Shockley diode equation - Structure of a solar cell - The solar cell equation - Fill factor and maximum power - Various electron - hole-pair recombination mechanisms - Crystalline silicon solar cells - Thin film solar cells: CIGS, Cite and a - silicon - Tandem solar cells - Dye - sensitized solar cells - Organic solar cells

### UNIT IV

#### CONCENTRATION OF SOLAR ENERGY

Three types of imaging optics: trough or linear collectors, central receiver with heliostats, and parabolic dish concentrator with on - axis tracking- Solar thermal electricity using Stirling engine or Ranking engine - Solar photovoltaic's with concentration.

### UNIT V

#### ENERGY STORAGE

Necessity of storage for solar energy- Chemical energy storage - Thermal energy storage - Thermal Flywheels - Compressed air- Rechargeable batteries.



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1. Duffie, J.A., and Beckman, W.A. "Solar Energy Thermal Process", John Wiley and Sons, New York, Jui Sheng Hsieh, Solar Energy Engineering, Prentice-Hall, 2007.
2. M. Stix, "The Sun An Introduction", Second Edition, Springer 2002.
3. Nelson, "The Physics of Solar Cells". Imperial College Press, 2003.
4. Rai, G.D., "Solar Energy Utilization", Khanna Publishers, N. Delhi, 2010.
5. Sukhatme S.P., "Solar Energy", Tata McGraw Hills P Co., 3rd Edition, 2008.
6. B.G. Streetman and S. Banerjee, "Solid State Electronic Devices", Sixth Edition, Prentice Hall, 2006.



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## **ADVANCED HEAT AND MASS TRANSFER** (Effective from the academic year 2022-2023 onwards)

**CODE: 22RME304**

### **UNIT I**

#### **CONDUCTION AND RADIATION HEAT TRANSFER**

One dimensional energy equations and boundary condition - three-dimensional heat conduction equations - extended surface heat transfer - conduction with moving boundaries - radiation in gases and vapour. Gas radiation and radiation heat transfer in enclosures containing absorbing and emitting media – interaction of radiation with conduction and convection.

### **UNIT II**

#### **TURBULENT FORCED CONVECTIVE HEAT TRANSFER**

Momentum and energy equations - turbulent boundary layer heat transfer - mixing length concept - turbulence model –  $k-\epsilon$  model - analogy between heat and momentum transfer – Reynolds, Colburn, Prandtl turbulent flow in a tube - high speed flows.

### **UNIT III**

#### **PHASE CHANGE HEAT TRANSFER AND HEAT EXCHANGER**

Condensation with shears edge on bank of tubes - boiling – pool and flow boiling - heat exchanger –  $\epsilon$  -- NTU approach and design procedure - compact heat exchangers.

### **UNIT IV**

#### **NUMERICAL METHODS IN HEAT TRANSFER**

Finite difference formulation of steady and transient heat conduction problems – discretization schemes – explicit - Crank Nicolson and fully implicit schemes - control volume formulation – steady one-dimensional convection and diffusion problems - calculation of the flow field – SIMPLER Algorithm.

### **UNIT V**

#### **MASS TRANSFER AND ENGINE HEAT TRANSFER CORRELATION**

Mass transfer - vaporization of droplets - combined heat and mass transfers - heat transfer correlations in various applications like I.C. engines - compressors and turbines.



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1. Yunus A.Cengal, "Heat and Mass Transfer – A practical Approach", 3rd edition, Tata McGraw Hill, 2007.
2. Holman.J.P, "Heat Transfer", Tata Mc Graw Hill, 2002.
3. Ozisik. M.N., "Heat Transfer – A Basic Approach", McGraw-Hill Co., 1985
4. Incropera F.P. and DeWitt. D.P., "Fundamentals of Heat & Mass Transfer", John Wiley & Sons, 2002.
5. Nag.P.K, "Heat Transfe"r, Tata McGraw-Hill, 2002
6. Ghoshdastidar. P.S., "Heat Transfer, Oxford University Press, 2004
7. Yadav, R., "Heat and Mass Transfer", Central Publishing House, 1995.



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## **INDUSTRIAL ROBOTICS AND EXPERT SYSTEMS**

(Effective from the academic year 2022-2023 onwards)

**CODE:22RME305**

### **UNIT 1**

#### **INTRODUCTION AND ROBOT KINEMATICS**

Definition need and scope of Industrial robots – Robot anatomy – Work volume – Precision movement – End effectors – Sensors. Robot Kinematics – Direct and inverse kinematics – Robot trajectories – Control of robot manipulators – Robot dynamics – Methods for orientation and location of objects.

### **UNIT-II**

#### **ROBOT DRIVES AND CONTROL**

Controlling the Robot motion – Position and velocity sensing devices – Design of drive systems – Hydraulic and Pneumatic drives – Linear and rotary actuators and control valves – Electro hydraulic servo valves, electric drives – Motors – Designing of end effectors – Vacuum, magnetic and air operated grippers.

### **UNIT-III**

#### **ROBOT**

Transducers and Sensors – Tactile sensor – Proximity and range sensors – Sensing joint forces – Robotic vision system – Image Representation - Image Grabbing –Image processing and analysis – Edge Enhancement – Contrast Stretching – Band Rationing - Image segmentation – Pattern recognition – Training of vision system.

### **UNIT-IV**

#### **ROBOT CELL DESIGN AND APPLICATION**

Robot work cell design and control – Safety in Robotics – Robot cell layouts – Multiple Robots and machine interference – Robot cycle time analysis. Industrial applications of Robots.

### **UNIT-V**

#### **ROBOT PROGRAMMING, ARTIFICIAL INTELLIGENCE AND EXPERT SYSTEMS**

Methods of Robot Programming – Characteristics of task level languages lead through programming methods – Motion interpolation. Artificial intelligence – Basics – Goals of artificial intelligence – AI techniques – problem representation in AI – Problem reduction and solution techniques - Application of AI and KBES in Robots.



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1. K.S.Fu, R.C. Gonzalez and C.S.G. Lee, “Robotics Control, Sensing, Vision and Intelligence”, Mc Graw Hill, 1987.
2. Yoram Koren,” Robotics for Engineers’ Mc Graw-Hill, 1987.
3. Kozyrey, Yu. “Industrial Robots”, MIR Publishers Moscow, 1985.
4. Richard. D, Klafter, Thomas, A, Chmielewski, Michael Negin, “Robotics Engineering-An Integrated Approach”, Prentice-Hall of India Pvt. Ltd., 1984.
5. Deb, S.R.” Robotics Technology and Flexible Automation”, Tata Mc Graw-Hill, 1994.
6. Mikell, P. Groover, Mitchell Weis, Roger, N. Nagel, Nicholas G. Odrey, “Industrial Robotics Technology, Programming and Applications”, Mc Graw-Hill, Int. 1986.
7. Timothy Jordanides et al, “Expert Systems and Robotics”, Springer-Verlag, New York, May 1991.



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## REFRIGERATION SYSTEMS DESIGN

(Effective from the academic year 2022-2023 onwards)

CODE:22RME306

### UNIT I

#### REFRIGERATION CYCLES - ANALYSIS

Development of Vapor Compression Refrigeration Cycle from Reverse Carnot Cycle- conditions for high COP-deviations from ideal vapor compression cycle, Multipressure Systems , Cascade Systems-Analysis.

### UNIT II

#### MAIN SYSTEM COMPONENTS

Compressor- Types, performance, Characteristics of Reciprocating Compressors, Capacity Control, Types of Evaporators & Condensers and their functional aspects, Expansion Devices and their Behavior with fluctuating load.

### UNIT III

#### REFRIGERANTS

Classification of Refrigerants, Refrigerant properties, Oil Compatibility, Environmental Impact- Montreal / Kyoto protocols-Eco Friendly Refrigerants. Different Types of Refrigeration Tools, Evacuation and Charging Unit, Recovery and Recycling Unit, Vacuum Pumps.

### UNIT IV

#### SYSTEM BALANCING & CONTROLS

Estimation of Cooling Load, System Equilibrium and Cycling Controls, Electric Circuits in- Refrigerators, Window A/C, Types of motors, Relays.

### UNIT V

#### OTHER REFRIGERATION CYCLES

Vapor Absorption Systems-Aqua Ammonia & LiBr Systems, Steam Jet Refrigeration Thermo Electric Refrigeration and Air Refrigeration cycles.

### SUGGESTED BOOKS:

1. Dossat R.J., Principles of refrigeration, John Wiley, S.I. Version (2001).
2. Stoecker W.F., Refrigeration and Air conditioning, McGraw-Hill Book Company, 1989.
3. Jordan and Priester , Refrigeration and Air conditioning 1985.
4. Goshnay W.B., Principles and Refrigeration, Cambridge, University Press, 1985.
5. Langley , Billy C., 'Solid state electronic controls for HVACR' pentice-Hall 1986.





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## **COMPOSITE AND POLYMER MATERIALS** (Effective from the academic year 2022-2023 onwards)

**CODE:22RME307**

### **UNIT I**

#### **PROPERTIES OF POLYMERS**

Chemistry and Classification of Polymers – Properties of Thermo plastics – Properties of Thermosetting Plastics – Applications – Merits and Disadvantages.

### **UNIT II**

#### **PROCESSING OF POLYMERS**

Extrusion – Injection Moulding – Blow Moulding – Compression and Transfer Moulding – Casting – Thermo Forming General Machining properties of Plastics – Machining Parameters and their effect – Joining of Plastics – Mechanical Fasteners – Thermal bonding – Press Fitting.

### **UNIT III**

#### **INTRODUCTION TO FIBRES AND COMPOSITE MATERIALS**

Fibres – Fabrication, Structure, properties and applications - Glass, Boron, carbon, organic, ceramic and metallic fibers whiskers– Matrix materials structure – polymers, – metals and ceramics – Physical and chemical properties.

### **UNIT IV**

#### **PROCESSING OF POLYMER MATRIX COMPOSITES**

Open mould process, bag moulding, compression moulding with BMC and SMC filament winding – pultrusion – centrifugal casting – injection moulding – structure, properties and application of PMC's – Carbon Matrix Composites - Interfaces – Properties – recycling of PMC.

### **UNIT V**

#### **PROCESSING OF METAL MATRIX COMPOSITES AND CERAMIC MATRIX COMPOSITES**

Solid state fabrication techniques – diffusion bonding – powder metallurgy techniques plasma spray, chemical and physical vapour deposition of matrix on fibres Chemical vapour infiltration – Sol gel – liquid state fabrication methods – infiltration – squeeze, casting – rheo casting – compocasting - Interfaces properties– application of MMC and ceramic matrix composites.



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## SUGGESTED BOOKS:

1. Krishnan K Chawla, “Composite Materials Science and Engineering”, International Edition, Springer, 2006
2. Harold Belofsky, “Plastics, Product Design and Process Engineering”, Hanser Publishers, 2002.
3. Bera.E and Moet.A, “High performance polymers”, Hanser Publishers, 2001.
4. Rauwendaal,C., “Polymer extrusion”, Hanser publishers, 2000.
5. Rosatao, D.V. “Blow moulding”, Hand Book, Hanser Publishers, 1989.
6. Seamour, E.B. “Modern Plastics Technology”, Prentice Hall, 2002
7. Mallick, P.K. and Newman.S., “Composite Materials Technology”, Hanser Publishers, 2003



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## **ADVANCES IN CASTING AND WELDING PROCESSES** (Effective from the academic year 2022-2023 onwards)

**CODE: 22RME308**

### **UNIT I**

#### **CASTING DESIGN**

Heat transfer between metal and mould — Design considerations in casting – Designing for directional solidification and minimum stresses - principles and design of gating and risering

### **UNIT II**

#### **CASTING METALLURGY**

Solidification of pure metal and alloys – shrinkage in cast metals – progressive and directional solidification — Degasification of the melt-casting defects – Castability of steel, Cast Iron, Al alloys , Babbit alloy and Cu alloy.

### **UNIT III**

#### **RECENT TRENDS IN CASTING AND FOUNDRY LAYOUT**

Shell moulding, precision investment casting, CO<sub>2</sub> moulding, centrifugal casting, Die casting, Continuous casting, Counter gravity low pressure casting, Squeeze casting and semisolid processes. Layout of mechanized foundry – sand reclamation – material handling in foundry pollution control in foundry — Computer aided design of casting.

### **UNIT IV**

#### **WELDING METALLURGY AND DESIGN**

Heat affected Zone and its characteristics – Weldability of steels, cast iron, stainless steel, aluminum, Mg , Cu , Zirconium and titanium alloys – Carbon Equivalent of Plain and alloy steels Hydrogen embrittlement – Lamellar tearing – Residual stress – Distortion and its control . Heat transfer and solidification - Analysis of stresses in welded structures – pre and post welding heat treatments – weld joint design – welding defects – Testing of weldment.

### **UNIT V**

#### **RECENT TRENDS IN WELDING**

Friction welding, friction stir welding – explosive welding – diffusion bonding – high frequency induction welding – ultrasonic welding – electron beam welding – Laser beam welding –Plasma welding – Electroslag welding- narrow gap, hybrid twin wire active TIG – Tandem MIG- modern brazing and soldering techniques – induction, dip resistance, diffusion processes – Hot gas, wave and vapour phase soldering. Overview of automation of welding in aerospace, nuclear, surface transport vehicles and under water welding.



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## SUGGESTED BOOKS:

1. ASM Handbook, Vol 15, "Casting", 2004
2. ASM Handbook vol.6, "Welding, Brazing & Soldering", 2003
3. Parmer R.S., "Welding Engineering and Technology", Khanna Publishers, 2002
4. Srinivasan N.K., "Welding Technology", Khanna Tech Publishers, 2002
5. Heineloper & Rosenthal, "Principles of Metal Casting", Tata McGraw Hill, 2000.
6. Jain P.L., "Principles of Foundry Technology", Tata McGrawHill Publishers, 2003
7. Carry B., "Modern Welding Technology", Prentice Hall Pvt Ltd., 2002
8. Iotrowski – "Robotic welding – A guide to selection and application" – Society of Mechanical Engineers, 1987.
9. Schwariz, M.M. – "Source book on innovative welding processes" – American Society for Metals (OHIO), 1981
10. Cornu.J. "Advanced welding systems" – Volumes I, II and III, JAICO Publishers, 1994.
11. Lancaster.J.F. – "Metallurgy of welding" – George Alien & Unwin Publishers, 1980



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## SUPPLY CHAIN MANAGEMENT

(Effective from the academic year 2022-2023 onwards)

CODE:22RME309

### UNIT I

#### INTRODUCTION AND SUPPLY CHAIN NETWORK DESIGN

Definition, house of supply chain – customer satisfaction, integration, coordination - decision phases in a supply chain, objectives of SCM, examples of supply chains, supply chain drivers, supply chain performance measures. SUPPLY CHAIN NETWORK DESIGN- Data collection – data aggregation, transportation modes and rates, mileage estimation, warehouse costs, warehouse capacity, potential warehouse locations, service level requirements and future demand. Network design in the supply chain – factors influencing the network design, framework for network design decisions, models for facility location and capacity allocation – capacitated plant location model, gravity location model, allocating demand to production facilitates, simultaneous location of plants and warehouses – impact of uncertainty on network design.

### UNIT II

#### INVENTORY MANAGEMENT AND STRATEGIC ALLIANCE

Single warehouse inventory model - cycle inventory – economies of scale to exploit fixed costs, quantity discounts, short term discounting, multi-echelon inventory, example problems. managing uncertainty – safety inventory in the supply chain –safety level estimation, impact of supply uncertainty, impact of aggregation, impact of replenishment policies, managing safety inventory in multi echelon supply chain, managing safety inventory in practice – product availability – optimal level, affecting factors, supply chain contracts – risk pooling – examples. value of information – Bullwhip effect, information and supply chain technology. STRATEGIC ALLIANCE - Framework for strategic alliance - 3PL and 4PL – retailer-supplier partnerships – distribution integration – procurement and outsourcing – benefits, make/buy decisions, E-Procurement, supplier relationship management – supplier scoring and assessment, supplier selection and contracts – E-Business and the supply chain. design for logistics- Reverse logistics –Cases in Paper industry – Furniture industry – supplier integration into new product development – mass customization.

### UNIT III

#### DISTRIBUTION NETWORK DESIGN AND STRATEGIES

Role of distribution in supply chain – distribution network design – factors influencing distribution network design. push strategy – pull strategy – Kanban replenishment systems, types, implementation, and push–pull strategy – demand driven strategy – impact of internet on supply chain strategy. distribution networks in practice – direct shipment, cross docking, warehousing, transshipment.



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## UNIT IV

### CUSTOMER VALUE AND GLOBAL SUPPLY CHAINS

Customer value – dimensions, strategic pricing, customer value measures, information technology and customer value – customer relationship management. global supply chains – introduction, driving factors, risks and advantages, issues, regional differences in logistics.

## UNIT V

### INFORMATION TECHNOLOGY FOR SCM

Goals – standardization – infrastructure – interface devices, communications, databases, system architecture – system components – integrating the supply chain information technology - DSS for supply chain management.

### SUGGESTED BOOKS:

1. Simchi – Levi Davi, Kaminsky Philip and Simchi-Levi Edith, “Designing and Managing the Supply Chain”, Tata McGraw Hill Publishing Company Ltd, New Delhi, 2003.
2. Chopra S and Meindl P, “Supply Chain Management: Strategy, Planning, and Operation”, Prentice Hall India Pvt. Ltd, New Delhi, 2007.
3. Robert B Handfield and Ernest L Nichols, “Introduction to Supply Chain Management”, Prentice Hall, Inc. New Delhi, 1999.
4. Sahay B S, “Supply Chain Management”, Macmillan Company, 2000.
5. David Brunt and David Taylor, “Manufacturing Operations and Supply Chain Management : The Lean Approach”, Vikas Publishing House, New Delhi, 2001.
6. Hartmud Stadler and Christoph Kilger, “Supply Chain Management and Advanced Planning: Concepts, Models, Software”, Springer-Verlag, 2000.
7. David F Ross, “Introduction to E-Supply Chain Management”, CRC Press, 2003



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## ENGINEERING METALLURGY

(Effective from the academic year 2022-2023 onwards)

CODE:22RME310

### UNIT I

#### SPECIAL STEEL

High strength low alloy (HSLA) steel, Dual phase steel, Duplex stainless steel, TRIP steel, Maraging steel, High speed steel, Stainless steel: ferritic, austenitic and martensitic. Precipitation & dispersion hardenable materials.

### UNIT II

#### AGE HARDENABLE ALLOYS

Al-Cu alloys, Al-Fe-V-Si alloys. Super alloys: Ni, Fe and Co based super alloys, Ti based alloys & their thermo mechanical treatment, Nano materials: Synthesis, properties and applications. ; Non-structural materials: Dielectric materials; dielectric constant and polarization, linear dielectric materials, capacitors and insulators, non-linear dielectrics, pyro, piezo and ferro-electrics properties;

### UNIT III

#### SEMICONDUCTOR

Direct and indirect band gap, band diagrams, applications of semiconductors, degenerate and non-degenerate semiconductors, extrinsic and intrinsic semiconductors. Superconducting materials, Optical & Photoionic materials, electron-hole-recombination.

### UNIT IV

#### BIOMATERIALS

Property requirements for biomaterials, concept of biocompatibility, important biometallic alloys; Ti based, stainless steel. Intelligent materials.

### SUGGESTED BOOKS:

1. W.F. Smith, "Principles of Materials Science and Engineering", McGraw Hill, New York (1994).
2. W.D. Callister, "An Introduction Materials Science & Engineering", John Wiley & Sons (2007).
3. V. Raghavan, "Material Science and Engineering", Prentice Hall of India, 2004.
4. R.Sharma, Sharma, "Heat Treatment: Principles and techniques", Prentice Hall of India, (2004).



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## SMART MANUFACTURING

(Effective from the academic year 2022-2023 onwards)

CODE:22RME311

### UNIT I

#### INTRODUCTION

Overview, and components of manufacturing systems, Design, operation, and control of manufacturing systems.

### UNIT II

#### TYPES OF MANUFACTURING SYSTEMS

Single station cells, manual assembly lines, automated production lines, transfer lines, analysis automated assembly systems.

### UNIT III

#### PERFORMANCE OF MANUFACTURING SYSTEM

Productivity, quality, reliability, agility, responsiveness, sustainability, utilization & availability, flexibility, reconfigurability, resiliency, efficiency and effectiveness of manufacturing system, metrics and key performance indicators.

### UNIT IV

#### GROUP TECHNOLOGY AND CELLULAR MANUFACTURING

Flexible manufacturing systems, changeable manufacturing systems, Just-In-Time and lean production, automation. Agile/demand driven manufacturing, Quick response manufacturing, world class manufacturing and holonic manufacturing systems.

### UNIT V

#### COMPUTER INTEGRATED MANUFACTURING

Enterprise Integration (ISA-95 and other standards), Digital Manufacturing and smart manufacturing systems.

### SUGGESTED BOOKS:

1. M. P. Groover, "Automation, Production systems and Computer Integrated Manufacturing". 3rd edition, Pearson Education, 2015. ISBN: 978-9332549814.
2. N. Singh, "Systems Approach to Computer Integrated Design and Manufacturing", 1st edition, Wiley India, 2011. ISBN: 978-8126530410.
3. G. Chryssolouris, "Manufacturing Systems: Theory and Practice". 2nd edition, Springer, 2006. ISBN: 978-1441920676.
4. W. J. Hopp, M. L. Spearman, "Factory Physics", 3rd edition, Waveland Press, 2011.





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5. E. Turban, L. Volonino, “Information Technology for Management: Transforming Organizations in the Digital Economy”, 7th edition, Wiley India Private Limited, 2010. ISBN: 978-8126526390.
6. R. Askin and C. Standridge, “Modeling and Analysis of Manufacturing Systems”, 1st edition, John Wiley, 1992. ISBN: 978-0-471-51418-3.



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## **INTELLIGENT INDUSTRIAL AUTOMATION AND ITS APPLICATION**

(Effective from the academic year 2022-2023 onwards)

**CODE:22RME312**

### **UNIT I**

#### **INTRODUCTION TO INDUSTRIAL AUTOMATION**

Intelligent Systems, Hydraulic Actuators for Industrial Automation, Principles and Strategies of Automation, Basic Elements of an Automated System, Advanced Automation Functions, Levels of Automations. Flow lines & Transfer Mechanisms, Fundamentals of Transfer Lines. (SLE: Analysis of Transfer Lines)

### **UNIT II**

#### **MATERIAL HANDLING AND IDENTIFICATION TECHNOLOGIES**

Overview of Material Handling Systems, Principles and Design Consideration, Material Transport Systems, Storage Systems, Overview of Automatic Identification Methods. (SLE: Material Identification Methods)

### **UNIT III**

#### **AUTOMATED MANUFACTURING SYSTEMS**

Components, Classification and Overview of Manufacturing Systems, Manufacturing Cells, GT and Cellular Manufacturing, FMS, FMS and its Planning and Implementation. Quality Control Systems: Traditional and Modern Quality Control Methods, SPC Tools, Inspection Principles and Practices, Inspection Technologies. (SLE: Usage of SPC tools using excel or Minitab).

### **UNIT IV**

#### **CONTROL TECHNOLOGIES IN AUTOMATION**

Industrial Control Systems, Process Industries Versus Discrete-Manufacturing Industries, Continuous Versus Discrete Control, Computer Process and its Forms. Introduction & Automatic Process Control, Building Blocks of Automation Systems: LAN, Analog & Digital I/O Modules, SCADA Systems & RTU. Distributed Control System: Functional Requirements, Configurations & some popular Distributed Control Systems. (SLE: Display Systems in Process Control Environment.)

### **UNIT V**

#### **AUTOMATION AND INDUSTRIAL CONTROL APPLICATIONS**

Electric Drives, Sensors and Vision used for automation, Trajectory planning, Automation Algorithm, Programming and flow control for automation. Modeling and Simulation for Plant Automation: Introduction, need for system Modeling, Building Mathematical Model of a Plant, Modern Tools & Future Perspective. Industrial Control Applications: Cement, Thermal, Water Treatment & Steel Plants. (SLE: Cases Studies minimum one for Cement, Thermal, Water Treatment & Steel Plants applications).



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## SUGGESTED BOOKS:

1. Automation, “Production Systems and Computer Integrated Manufacturing”, M.P. Groover, Pearson Education. 5th edition, 2009.
2. “Computer Based Industrial Control”- Krishna Kant, PHI, 2nd edition, 2010
3. “An Introduction to Automated Process Planning Systems”- Tiess Chiu Chang & Richard A. Wysk.
4. “Performance Modeling of Automated Manufacturing Systems”, -Viswanandham, PHI, 1st edition, 2009.
5. G.S. Hegde, “A Textbook on Industrial Robotics”, University Science Press, Second Edition 2008, ISBN 978-81-318-051803



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## **ALTERNATIVE FUELS FOR IC ENGINES** (Effective from the academic year 2022-2023 onwards)

**CODE:22RME313**

### **UNIT I**

#### **ALTERNATE FUELS**

Estimation of petroleum reserve - Need for alternate fuel - Availability and properties of alternate fuels – general use of alcohols - LPG - Hydrogen - Ammonia, CNG and LNG - Vegetable oils and Biogas – Solar – Merits and demerits of various alternate fuels;

### **UNIT II**

#### **PROPERTIES OF ALCOHOLS AND CNG**

Properties, alcohols and gasoline blends, performance in SI engine. Methanol and gasoline blends - Combustion characteristics in engines - emission characteristics – Engine modifications; Availability of CNG, properties, modification required to use in engines - performance and emission characteristics of CNG using LPG in SI & CI engines.

### **UNIT III**

#### **ENGINE MODIFICATION AND PERFORMANCE**

Performance and emission for LPG – Hydrogen – Storage and handling, performance and safety aspects; Various vegetable oils for engines – Single and dual fuel use – Engine modifications - SVO - Esterification - Performance in engines - Performance and emission characteristics;

### **UNIT IV**

#### **LAYOUT OF AN ELECTRIC VEHICLE**

Layout of an electric vehicle - Advantage and limitations - Specifications - System component.

### **UNIT V**

#### **VEHICLE SYSTEM**

Electronic control system - High energy and power density batteries - Hybrid vehicle - Solar powered vehicles.

### **SUGGESTED BOOKS:**

1. M. Dayal, “Energy today & tomorrow”, I & B Horishr India, 1982.
2. Nagpal, “Power Plant Engineering”, Khanna Publishers, 1991.
3. “Alcohols and motor fuels progress in technology”, Series No.19, SAE Publication USA 1980 SAE PaperNos. 840367, 841156, 841333, 841334
4. “The properties and performance of modern alternate fuels” - SAE Paper No.841210. SAE Handbook



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## **ENERGY CONSERVATION AND MANAGEMENT**

(Effective from the academic year 2022-2023 onwards)

**CODE:22RME314**

### **UNIT I**

#### **ENERGY SOURCES**

Classification and characterization of fuels (fossil and bio-fuel), conversion and utilization, environmental and economic issues, optimum use of energy resources,

### **UNIT II**

#### **BOILERS, ICE and GAS TURBINES**

Thermodynamic cycles, Principles of thermal energy conversion in boilers, internal combustion engines and gas turbines, cogeneration and combined cycle power generation.

### **UNIT III**

#### **ENERGY MANAGEMENT**

Fuel cells and MHD technology, solar, wind and nuclear power, utilization of industrial heat, Energy management in industry.

### **UNIT IV**

#### **POLLUTION CONTROL**

Environmental and economic evaluation advanced pollution control technology.

### **SUGGESTED BOOKS:**

1. R. Gold Stick and A. Thumann, "Principles of Waste Heat Recovery", PHI, 1986.
2. D. Y. Goswami, F. Kreith, "Energy Conversion"- CRC Press, 2007
3. V. Kadambi, and M. Prasad, "Introduction to energy conversion turbo machinery: Energy conversion cycle"-Wiley Eastern, New Delhi, 1974,



## FUEL CELL TECHNOLOGY

(Effective from the academic year 2022-2023 onwards)

CODE:22RME315

### UNIT I

#### INTRODUCTION

Overview of current fuel cell technology. Operating principles, fundamental thermodynamics and electrochemistry.

### UNIT II

#### TYPES OF FUEL CELLS AND APPLICATIONS

Proton exchange membrane fuel cells; components; performance; testing. Micro fuel cells. High temperature fuel cells. Modelling of transport phenomena in fuel cells.

### UNIT III

#### HYDROGEN PRODUCTION AND STORAGE.

Fuel cell systems and ancillaries. Overview and status of various fuel cell technologies. Fundamentals: fuel cell thermodynamics; electrode kinetics; performance and efficiency; transport processes.

### UNIT IV

#### FUELLING ISSUES

Proton Exchange Membrane Fuel Cells (PEMFCs). Solid Oxide Fuel Cells (SOFCs). Fuelling issues. Fuel cell systems and applications.

### SUGGESTED BOOKS:

1. A.V. Da Rosa, 2005, "Fundamentals of Renewable Energy Processes", Elsevier academic press.
2. W. Vielstich, A. Lamm and H.A. Gastieger, 2003, "Handbook of Fuel Cells", vol. 1-4, John Wiley.
3. G. Hogen ed. 2003, "Fuel Cell Technology Handbook", CRC press.



## **MICRO-MACHINING AND PRECISION ENGINEERING** (Effective from the academic year 2022-2023 onwards)

**CODE:22RME316**

### **UNIT I**

#### **INTRODUCTION TO MICROMACHINING TECHNOLOGIES**

Introduction to micromachining technologies, bulk micromachining, LIGA, Surface Micromachining, Characterization of micro-machining, Tool making, Micromachinability of materials.

### **UNIT II**

#### **DIAMOND MICRO-MACHINING**

Machining principles, diamond turning, diamond grinding, accuracy and dimensional control, molecular dynamics simulation of the atomic processes in micro-machining, principles of molecular dynamics, atomistic forces of chip formation and surface generation, future trends in ultrahigh speed machining.

### **UNIT III**

#### **MICROELECTRO DISCHARGE MACHINING**

Principles of micro-EDM, micro-EDM by Die-sinking and WEDG, micro-WEDM, micro-WEDG, micro-ECM, Principles of micro-turning, micro-drilling and micro-milling, hybrid micro-machining method, on-line measurement by machine vision and integrated probe.

### **UNIT IV**

#### **ABRASIVE MICROMACHINING AND MICRO GRINDING**

Abrasive micromachining mechanisms, micro-grinding mechanism, micro-machining rate, micro-machining cooling media. ; Laser micromachining: Principles of laser material removal, laser micro-drilling, laser micro-adjustment, laser surface structuring, laser micro-cutting.

### **UNIT V**

#### **MICRO-MACHINING BY FINISHING TECHNIQUES**

Micro-lapping, micro-machining, magneto-abrasive micromachining and finishing (MAF), ELID Grinding.; Measuring Techniques in micro-machining: stylus instruments, scanning tunneling microscopes, atomic force microscope, measurement of micromoles and slots using optical method, vibro-scanning method, elastic transmission method, computer aided measurement testing and diagnostics, surface integrity and other related measurements.



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## SUGGESTED BOOKS:

1. J. M. Geough, "Micro-machining of Engineering Materials", Edited by Marcel Dekker, 2002.
2. R.W. Johnstone, M. Parameswaran, "An introduction to surface-micromachining", Kluwer Academic Publishers, 2004.
3. N. P Mahalik. "Micro-manufacturing and nano-technology", edited by, Springer Publication, 2006.
4. M. P. Groover, "Automation, Production Systems and Computer-Integrated Manufacturing", 2003.





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## OPTIMIZATION TECHNIQUES

(Effective from the academic year 2022-2023 onwards)

CODE: 22RME317

### UNIT I

#### NONLINEAR OPTIMIZATION

Introduction – unconstrained optimization - one-dimensional optimization – elimination methods – Fibonacci method, golden section methods – interpolation methods – quadratic, direct route method – multivariable optimization - direct search methods – pattern search methods – univariate method, hooks and jeeves method, simplex method – descent methods – steepest descent, Newton methods.

### UNIT II

#### CONSTRAINED NONLINEAR OPTIMIZATION

Direct methods – the complex method, cutting plane method – indirect methods – interior and exterior penalty function methods, Khun-Tucker conditions, Lagrangian method.

### UNIT III

#### INTEGER AND DYNAMIC PROGRAMMING

Introduction to integer programming – solution techniques - graphical method, the branch and bound technique, gomary’s cutting plane method, examples on the application in manufacturing / design systems – introduction to dynamic programming - bellman’s principle of optimality, examples on the application on routing problem, inventory problem.

### UNIT IV

#### NETWORK OPTIMIZATION MODELS

Terminology of networks – the shortest route problem – the minimum spanning tree problem – the maximum flow problem – the minimum cost flow problem – the network simplex method.

### UNIT V

#### NON TRADITIONAL OPTIMIZATION MODELS

Introduction to non-traditional optimization, computational complexity – NP-hard, NP-complete, no free lunch theorem – working principles of simulated annealing, Tabu search, and neural networks, simple applications. Introduction to Genetic Algorithms, Ants Colony Algorithm, Particle Swarm Algorithm, Hybrid Algorithms, Simple Applications.



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## SUGGESTED BOOKS:

1. Singiresu S Rao, “Engineering Optimization: Theory and Practice”, Wiley-Interscience, Third Edition, 1996.
2. Kalyanmoy Deb, “Optimization for engineering design”, Prentice Hall India Pvt. Ltd., New Delhi, 2000.
3. David E Goldberg, “Genetic Algorithms in Search, Optimization and Machine Learning”, Addison Wesley Pub Co., 1989.
4. Marco Dorigo and Thomas Stutzle, “Ant Colony Optimization”, Prentice Hall of India, 2005.
5. Maurice Clerc, “Particle Swarm Optimization”, ISTE, 2007
6. Dimitri P Bertsekas, “Dynamic Programming: Deterministic and Stochastic Models”, Prentice Hall, 1987.
7. Stephen G Nash and Ariela Sofer, “Linear and Nonlinear Programming”, McGraw Hill College Div., 1995.
8. Fred Glover, Manuel Laguna and Fred Laguna, “Tabu Search”, Kluwer Academic Publishers, 1997.



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## COMPUTATIONAL METHODS

(Effective from the academic year 2022-2023 onwards)

CODE: 22RME318

### UNIT I

#### INTRODUCTION TO COMPUTATIONAL METHODS

Examples, solving sets of equations, Gauss elimination method, Choleski method, Iterative methods, Relaxation method, system of non-linear equations- Newton Raphson method, computer programs.

### UNIT II

#### NUMERICAL INTEGRATION

Newton-Cotes integration formulas, Trapezoidal rule, Simpson's rules, Gaussian quadrature, adaptive integration, cubic spline functions - Bezier curves and B-splines, computer programs. Boundary value problems and characteristic value problems: Shooting method, solution through a set of equations, derivative boundary conditions, Rayleigh-Ritz method, characteristic value problems, solution using characteristic polynomial method, Jacobi method, power method and Inverse power method.

### UNIT III

#### NUMERICAL SOLUTION OF PARTIAL DIFFERENTIAL EQUATIONS

Laplace's equations, representations as a difference equation, Iterative methods for Laplace's equations, Poisson equation, derivative boundary conditions, irregular and non-rectangular grids, Matrix patterns, Sparseness, ADI method, applications to heat flow problems, computer programs.

### UNIT IV

#### PARABOLIC PARTIAL DIFFERENTIAL EQUATIONS

Explicit method, Crank-Nicholson method, derivative boundary condition, stability and convergence criteria, Parabolic equations in two or more dimensions, applications to heat flow problems, computer programs. Hyperbolic Partial differential equations: Solving wave equation by finite differences, stability of numerical method, method of characteristics, Wave equation in two space dimensions, computer programs.

### UNIT V

#### CURVE FITTING AND APPROXIMATION OF FUNCTIONS

Least square approximation, fitting of non-linear curves by least squares, regression analysis, computer programs.



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## SUGGESTED BOOKS:

1. Curtis F Gerald and Patrick O Wheatley, “Applied Numerical Analysis”, Pearson Education, 2002.
2. Rajasekaran S, “Numerical Methods in Science and Engineering – A Practical Approach”, Wheeler Publishing, 1999, Second Edition.
3. Douglas J Faires and Riched Burden, “Numerical Methods”, Brooks/Cole Publishing Company, 1998, Second Edition.
4. Steven C Chapra and Raymond P Canale, “Numerical Methods for Engineers with Software and Programming Applications”, Tata McGraw Hill Edition, 2004.
5. John H Mathews and Kurtis D Fink, “Numerical Methods using MATLAB”, Prentice Hall, 1998.
6. Ward Cheney and David Kincaid, “Numerical Mathematics and Computing”, Brooks/Cole Publishing Company, 1999, Fourth Edition.



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## FINITE ELEMENT ANALYSIS

(Effective from the academic year 2022-2023 onwards)

CODE:22RME319

### UNIT I

#### BENDING OF PLATES AND SHELLS

Review of Elasticity Equations – Bending of Plates and Shells – Finite Element Formulation of Plate and Shell Elements - Conforming and Non-Conforming Elements – C0 and C1 Continuity Elements – Degenerated shell elements- Application and Examples.

### UNIT II

#### NON-LINEAR PROBLEMS

Introduction – Iterative Techniques – Material non-linearity – Elasto Plasticity – Plasticity – Visco Plasticity – Geometric Non linearity – large displacement Formulation –Solution procedure- Application in Metal Forming Process and Contact Problems.

### UNIT III

#### DYNAMIC PROBLEM

Direct Formulation – Free, Transient and Forced Response – Solution Procedures – Eigen solution- Subspace Iterative Technique – Response analysis-Houbolt, Wilson, Newmark – Methods – Explicit & Implicit Methods- Lanchzos, Reduced method for large size system equations.

### UNIT IV

#### FLUID MECHANICS AND HEAT TRANSFER

Governing Equations of Fluid Mechanics – Solid structure interaction - Inviscid and Incompressible Flow – Potential Formulations – Slow Non-Newtonian Flow – Metal and Polymer Forming – Navier Stokes Equation – Steady and Transient Solution.

### UNIT V

#### ERROR ESTIMATES AND ADAPTIVE REFINEMENT

Error norms and Convergence rates – h-refinement with adaptivity – Adaptive refinement.

### SUGGESTED BOOKS:

1. Zienkiewicz, O.C. and Taylor, R.L., “The Finite Element Method”, Fourth Edition, Volumes 1 & 2, McGraw Hill International Edition, Physics Services, 1991.
2. Cook R.D., “Concepts and Applications of Finite Element Analysis”, John Wiley and Sons Inc., New York, 1989.
3. Bathe K.J., “Finite Element Procedures in Engineering Analysis”, Prentice Hall, 1990.