Savitribai Phule Pune University
Faculty of Science & Technology

Curriculum/Syllabus
For
Honors in "3D Printing"

Bachelor of Engineering
(Choice Based Credit System)

Honors in Major Disciplines of Mechanical Engineering, Mechanical Engineering (Sandwich) Production Engineering, Production Engineering (Sandwich), Automobile Engineering and Civil Engineering - (2019 Course)

Board of Studies – Mechanical and Automobile Engineering
(With Effect from Academic Year 2021-22)

Savitribai Phule Pune University

Board of Studies - Automobile and Mechanical Engineering

Undergraduate Program - Mechanical Engineering (2019 pattern)

Honors in "3D Printing"

Course Code	Course Name	Teaching Scheme (Hrs./week)			Examination Scheme and Marks						Credit			
		TH	PR	TUT	ISE	ESE	TW	PR	OR	Total	TH	PR	TUT	Total
Semester-V														
302011MJ	Additive Manufacturing Technology	4	-	-	30	70	-	-	-	100	4	-	-	4
302012MJ	Modelling Lab	-	2	-	-	-	50	-	-	50	-	1	-	1
	Total	**4**	**2**	**-**	**30**	**70**	**50**	**-**	**-**	**150**	**4**	**1**	**-**	**5**
Semester-VI														
302013MJ	Design for Additive Manufacturing	4	-	-	30	70	-	-	-	100	4	-	-	4
	Total	**4**	**-**	**-**	**30**	**70**	**-**	**-**	**-**	**100**	**4**	**-**	**-**	**4**
Semester-VII														
402014MJ	Additive Manufacturing System Design	4	-	-	30	70	-	-	-	100	4	-	-	4
402015MJ	3D Printing Lab	-	2	-	-	-	50	-	-	50	-	1	-	1
	Total	**4**	**2**	**-**	**30**	**70**	**50**	**-**	**-**	**150**	**4**	**1**	**-**	**5**
Semester-VIII														
402016MJ	3D Printing Applications & Entrepreneurship	4	-	-	30	70	-	-	-	100	4	-	-	4
402017MJ	Seminar	-	-	2	-	-	50	-	-	50	-	-	2	2
	Total	**4**	**-**	**2**	**30**	**70**	**50**	**-**	**-**	**150**	**4**	**-**	**2**	**6**

Abbreviations: TH: Theory, **PR**: Practical, **TUT**: Tutorial, **ISE**: In-Semester Exam, **ESE**: End-Semester Exam, **TW**: Term Work, **OR**: Oral

1.Rules and Regulations for Honors / Minors Programs

R1.1 It is absolutely not mandatory to any student to opt for Honours or Minors Program. Choice is given to individual student to undertake Honors/Minors programs from the third year engineering (Fifth Semester) to fourth year engineering (Eighth Semester). Honors/Minors programs will be opted from offered programs by SPPU. Once selected he/she will not be permitted to change the Honors/Minors program in forthcoming semesters.

R1.2 The registration for Honors/Minors Programme will lead to gain additional credits to such students. The result of Honours/Minors Program will get reflected in ledgers to be maintained at University only. After the completion of the Honors/Minors program by concerned students, details of credits earned in Honors/Minors program be printed in the mark sheet of eighth semester. For those students, who will not be able to complete Honors/Minors program, details about the additional credits earned will not get printed.

R1.3 Credits earned through registration and successful completion of the Honors/Minors Programme will **not** be considered for the calculation of SGPA or CGPA.

As per the standard practice, SGPA and CGPA calculations will be done with common base only by considering mandatory credits assigned for the Bachelor programme as per the structure approved by the Academic Council.

R1.4 Students once registered for the programme need to complete all credits assigned for the specific Honors and Minors Programme in the period of 4 years from the Semester-V. Degree with

Honors/Minors will be awarded only after the completion of Honors/Minors Programme along with respective UG program degree.
Student may opt to cancel the registration for Honors/Minors within this period of 4 years. After 4 years expire automatically Bachelor's degree will be awarded to such a student provided he/she has earned the credits needed for graduation.
R1.5 Backlog Honors/Minors courses will not contribute in the decision of A.T.K.T.

2. Examination Scheme:

R2.1 Examinations for Honors/Minors Program will get organized at the University Level. Question paper will be common for all students who had opted/registered for the specific Honors/Minors Program. Evaluation of answer books for Honors/Minors program will be done at the university level.
R.2.2 Additional examination fees as per prevailing rules and regulations will be charged from those students who had registered for Honors/Minors Program to match the expenses for paper setting and the assessment of answer books at the CAP Centre.

Instructions:

- Minimum number of Experiments/Assignments in PR/Tutorial shall be carried out **as mentioned in the syllabi** of respective courses.
- Assessment of tutorial work has to be carried out similar to term-work. The Grade cum marks for Tutorial and Term-work shall be awarded on the basis of **continuous evaluation.**

302011MJ: Additive Manufacturing Technology					
Teaching Scheme		**Credits**		**Examination Scheme**	
Theory	**4 Hrs./Week**	**Theory**	**4**	**In-Semester**	**30 Marks**
				End-Semester	**70 Marks**

Prerequisites: Solid Modelling& Drafting, Engineering Materials

Course Objectives:

1. To know the principle, methods, possibilities and limitations as well as environmental effects of Additive Manufacturing technologies.
2. To be familiar with the characteristics of the different materials those are used in Additive Manufacturing technologies.
3. To explore the potential of additive manufacturing in different industrial sectors.

Course Outcomes:

On completion of the course the learner will be able to;

CO1. Understand the fundamentals of Additive Manufacturing Technologies for engineering applications.

CO2. Understand the methodology to manufacture the products using extrusion-based deposition technologies and study their applications, advantages and case studies.

CO3. Understand the methodology to manufacture the products using light based photo-curing technologies and study their applications, advantages and case studies.

CO4. Understand the methodology to manufacture the products using laser-based melting& light engineered technologies and study their applications, advantages and case studies.

CO5. Evaluate the process parameters of AM technologies to improve the quality of the parts produced.

CO6. Able to apply knowledge of additive manufacturing for various real-life applications.

Course Contents

Unit 1	**Additive Manufacturing (AM) Overview**

Introduction to AM, Historical Development, Additive v/s Conventional Manufacturing, Role of AM in Product development cycle, Rapid prototyping, Relevance of AM in Industry 4.0, Current industry and manufacturing trends driving AM, AM Process-Chain, Reverse engineering, Advantages, Types of materials, Classification of AM Processes (Process-based, material form-based, application-based - direct and indirect processes and Micro- and Nano-additive processes), Process Planning for Additive Manufacturing.

Unit 2	**AM Processes & Extrusion-based Deposition Technologies**

Additive manufacturing processes: Extrusion, Jetting, Photo-polymerization, Powder bed fusion, Direct-write, Sheet lamination, Directed-energy deposition and the latest state of the art processes

Process and mechanism, Materials, Process Physics, Parameters, Benefits, Drawbacks, Limitations and Applications of

Extrusion-Based Deposition: Fused Deposition Modeling (FDM), Fused Filament Fabrication (FFF), Direct Ink Writing (DIW), Robocasting, Bio-printing.

Unit 3	Light Based Photo-curing Technologies
Process and mechanism, Materials, Process Physics, Parameters, Benefits, Drawbacks, Limitations and Applications of **Light-Based Photo-curing**: Stereolithography (SLA), Digital Light Processing (DLP), Direct Laser Writing (DLW), Continuous Liquid Interface Production (CLIP)	
Unit 4	**Laser-Based Melting& Light Engineered Technologies**
Process and mechanism, Materials, Process Physics, Parameters, Benefits, Drawbacks, Limitations and Applications of **Laser-Based Melting**: Selective Laser Sintering (SLS), Direct Metal Laser Sintering (DMLS), Selective Laser Melting (SLM), Electron-Beam Melting (EBM), Laser Blown Powder, Laser Wire Deposition, Laser Engineered Net Shaping (LENS)	
Unit 5	**Inkjet(droplet)Based Deposition and Fusion Technologies**
Process and mechanism, Materials, Process Physics, Parameters, Benefits, Drawbacks, Limitations and Applications of **Inkjet(droplet)-Based Deposition and Fusion**: Multi-jet Modeling (MJM), Polyjet Printing, Nanoparticle Jetting, Binder Jetting, Multi-Jet Fusion, Color-jet Printing (CJP), **Energy Deposition Techniques**: Plasma/TIG/MIG/Arc Deposition, Electron Beam-based DED, Direct Metal Deposition (DMD), 3D Laser Cladding.	
Unit 6	**Case Studies, Application and Special Topics**
C**ase Studies and Application of AM**: 3D printing in prominent industries (Aerospace, Electronics, Defense, Automotive, Construction, Architectural, Machine-Tools), Other industrial applications (Health-Care, Personalized Surgery, Bio-medical Applications, Assistive Devices, Food-Processing, Food & Consumer Applications, Art, Fashion, Jewelry, Toys & Other Applications, etc), **Special Topics:**4D/5D Printing, Bio-printing, Bio-materials, scaffolds and tissue and Organ Engineering, Mass Customization and Future trends.	

Books and other resources

Text Books:

1. Chua Chee Kai, Leong Kah Fai, "3D Printing and Additive Manufacturing: Principles & Applications", 4th Edition, World Scientific, 2015
2. Amit Bandyopadhyay, Susmita Bose, "Additive manufacturing", CRC Press, Taylor & Francis Group, 2016
3. Ian Gibson, David W. Rosen, Brent Stucker "Additive Manufacturing Technologies: Rapid Prototyping to Direct Digital Manufacturing" Springer, 2010

References Books:

1. L. Lu, J. Y. H. Fuh and Y.S. Wong, "Laser-Induced Materials and Processes for Rapid Prototyping", Springer, 2001
2. Andreas Gebhardt and Jan-Steffen Hötter, "Additive Manufacturing: 3D Printing for Prototyping and Manufacturing" Hanser Publishers, Munich, 2016.
3. Ben Redwood, FilemonSchöffer& Brian Garret, "The 3D Printing Handbook: Technologies, design and applications", 3D Hubs B.V. 2017
4. Ehsan Toyserkani, Amir Khajepour, Stephen F. Corbin, "Laser Cladding", CRC Press, 2004
5. Andreas Gebhardt, "Understanding Additive", Hanser Publishers, Munich, 2011
6. Ben Redwood, Filemon Schöffer & Brian Garret, "The 3D Printing Handbook – Technologies, Design and Applications" Part One:3D Printing Technologies and Materials, 3D Hubs, 2017
7. Chee Kai, Kah Fai, Chu Sing, 'Rapid Prototyping: Principles and Applications", 2nd Ed., 2003
8. D. T. Pham and S.S. Dimov, "Rapid Manufacturing" Springer, 2001
9. Rupinder Singh J. Paulo Davim, "Additive Manufacturing - Applications and Innovations" CRC Press Taylor& Francis Group, 2019

10. I. Gibson, D. W. Rosen, B. Stucker, “Additive Manufacturing Technologies” Springer, 2010
11. L. Jyothish Kumar, Pulak M. Pandey, David Ian Wimpenny, “3D Printing and Additive Manufacturing Technologies” Springer, 2019

Web References:

1. NPTEL Course on Fundamentals of Additive Manufacturing Technologies by Prof. SajanKapil, IIT Guwahati, https://onlinecourses.nptel.ac.in/noc21_me115/preview
2. Introduction to Additive Manufacturing, https://www.youtube.com/watch?v=LCQoi10cGTo NPTEL IIT Kanpur, “Rapid Manufacturing”, Dt. Janakarajan Ramkumar Prof. Amandeep Singh, https://onlinecourses.nptel.ac.in/noc20_me50/preview

302012MJ: Modelling Lab					
Teaching Scheme		**Credits**		**Examination Scheme**	
Practical	**2 Hrs./Week**	**Practical**	**1**	**Term Work**	**50 Marks**

Prerequisites: Engineering Graphics, Solid Modelling & Drafting

Course Objectives:

1. Apply Conceptual Design and Geometric Modeling for AM
2. Manipulate various Data formats
3. Convert part file into STL format and Repair using different software tools
4. Determine part orientation for minimum build time and part errors

Course Outcomes:

On completion of the course, learner will be able to

CO1. Develop CAD models for 3D printing, Select and use correct CAD formats in the manufacture of 3D printed parts
CO2. Import and Export CAD data and generate STL file/s
CO3. Identify STL file problems and apply Repair Algorithms
CO4. Develop STL file for CAD models with appropriate Support Structures and Orientation
CO5. Apply techniques of CAD and Reverse Engineering for Geometry Transformation
CO6. Make use of Point Cloud Data (PCD) to reconstruct Industrial and Medical components

Guidelines for Laboratory Conduction

The student shall complete the following hands-on activities as a Term Work under the guidance of concerned faculty member. The open source software shall be preferred for conduction of practical.

Term Work

The learner shall complete minimum 10 of the following activities as a Term-Work:

List of Practical

1. Identification of a product for Additive Manufacturing and its Geometric Modeling
2. Working with CAD Data Exchange formats
3. Slicing of corrected STL files
4. Identification of problems associated with STL file
5. Object Scanning using 3D Scanner
6. Conversion of CT/MRI Medical scan data into STL file
7. Application of Repair Algorithms to make error-free CAD models
8. Part orientation, Support structure and Tool Path generation
9. Estimation of Build-time and Material for Model and Support structure generation
10. Simulation for optimization of Build-time and Material consumption
11. Generation of Tool Path data for 3D Printing of the physical part on RP machine
12. Industrial Visit and Report on visit to AM facility

302013MJ: Design for Additive Manufacturing					
Teaching Scheme		**Credits**		**Examination Scheme**	
Theory	**4 Hrs./Week**	**Theory**	**4**	**In-Semester**	**30 Marks**
				End-Semester	**70 Marks**

Prerequisites: Solid Modelling & Drafting, Engineering Materials, Additive Manufacturing Technology

Course Objectives:

1. To understand the importance of product design considerations for additive manufacturing
2. To be familiar with the characteristics of the different materials used in Additive Manufacturing technologies
3. Learn to create physical objects that satisfy product development/prototyping requirements

Course Outcomes:

On completion of the course the learner will be able to;

CO1. Select the suitable material and process for fabricating a given product
CO2. Design and develop a product for AM Process
CO3. Understand and analyze the additive manufacturing process to predict the build behavior.
CO4. Understand and apply the requirements for pre-processing, in-situ processing and post-processing
CO5. Create, manipulate and optimize the component to be printed using AM
CO6. Apply techniques of CAD and reverse engineering for geometry creation and transformation.

Course Contents

Unit 1	**Design for AM**

AM technology selection, Build strategies, Minimum feature size, Surface finish, Elimination of support structures, Guidelines for internal geometry like flow paths, cooling channels, cavities and others, Guidelines for making lightweight objects, Guidelines for making functionally gradient objects, DfAM: Process specific strategies, Rules and Recommendations

Unit 2	**Materials Science for AM**

Multi-functional and Multi-graded materials in AM, Role of solidification-rate, Evolution of non-equilibrium structure, Micro-structural studies, Structure-Chemical property relationship, Mechanical properties of materials

Materials: Metals, Polymers, Ceramics & Bio-ceramics, Composites, Hierarchical Materials, Biomimetic Materials, Shape-Memory Alloys, 4D Printing & Bio-active materials, Material selection

AM Material specific Process Parameters: Processes, Heat or Chemical Treatments, Phase Transformations, Process Selection for various applications and Material Science Considerations

Forms of raw material: Preparation, desired properties

Support Materials: Properties, Applications, Strategies, material and technology specific support structures, and support structure removal process

Unit 3	Mathematical Models for AM

Limitations of AM Systems: Defects and its rectification, Form, fit, function trade-off, time Vs cost

Mathematical models for AM: Selection of AM technologies using decision methods, AM process plan, Introduction to models for Monitoring and control of defects, Transformation, Distortion control methods

Chemical behavior of materials: Integration of chemistry, phase-equilibria, and Thermodynamics of a Materials and allied systems

Transport phenomena models: Temperature History, Fluid Flow History, Material Composition

Residual history: Stresses, Thermal Strains, Warpages, etc

Process Monitoring and Control: Defects, Geometry, Temperature, Composition and Phase Transformation

Unit 4	Process Design in AM

Pre-processing, In-Situ processing and Post-Processing for AM

3D Slicing and Multi-axis Path Planning: Classification and Types of slicing, 3D Slicing Strategies

Path Planning: Classification and Types of 2D and 3D Path Planning, Path Sequencing Strategy, Techniques of multi-printing modes

Post-Processing techniques: Requirements and Techniques, Support Removal, Sanding, Acetone treatment, Polishing, Heat treatments, Hot isostatic pressing, Materials science, Surface enhancement Techniques and its Material Science

Analysis of AM's error sources

Unit 5	Digital 3D Model Creation and Topology Optimization for AM

Digital input for AM, Layer Slicing, Infill Structure Techniques and it's Selection, Support Structure Integration, Voxel/Deposition Point Considerations,

CAD Data Exchange: Software Tools vs. Requirements, Sculpting & Repairing Data, 3D creation or reconstruction, Issues faced during 3D model creation, AM CAD Data/file formats for Engineering and Non-Engineering Applications, CAD Standards, Tool Path file formats, Software Customization & Automation

Analysis & Optimization: Algorithms, Use of FEA, CFD Techniques, Continuum and Discrete Element Methods, Topology Optimization and Use of Software

Point Cloud and other Scanned Data Processing: Translation, Data loss, Repair, Detail on NURBS, Model Validation

Standards: CAD specific and Material specific ISO and ASTM Standards

Unit 6	Reverse Engineering (RE)

Conventional use of Reverse Engineering Procedure, Digitization Methods,

Measuring Devices: Classification and Types, Advantages, Disadvantages, Limitations

3D Scanning: Scanning Process ,3D Scanners(Classification and Types,)

Software: Medical image control system software, Engineering Scanning and Data Conversion Software

CAD Model Construction: Point Clouds Data, Pre-processing, Point Clouds to Surface Model Creation, Classification and Types, NURBS surface model generation and its software use, Medical Data Processing, Data Handling and Reduction Methods

Scanned Geometry Refinement: Smooth the Surface, Remove Bumps and Blobs, Cleanup, Repair, other relevant Techniques

Applications of RE: Product Development and Manufacturing, Entertainment, Biomedical Engineering, etc

Books and other resources
Text Books: 1. Ali K. Kamrani, Emad Abouel Nasr, "Engineering Design and Rapid Prototyping" Springer, 2010 2. Ben Redwood, Filemon Schöffer& Brian Garret, "The 3D Printing Handbook – Technologies, Design and Applications" Part Two: Designing for 3D Printing, 3D Hubs, 2017 3. Chee Kai Chua, Chee How Wong, Wai Yee Yeong' "Standards, Quality Control, and Measurement Sciences in 3d Printing and Additive Manufacturing" Academic Press, 2017 4. Liza Wallach Kloski and Nick Kloski, "Getting Started with 3D Printing" Part III CAD Tutorials, Maker Media, 2016
References Books: 1. Leary Martin, "Design for Additive Manufacturing (Additive Manufacturing Materials and Technologies)" , Elsevier, 2019 2. Andreas Gebhardt, "Understanding Additive", Hanser Publishers, Munich, 2011 3. Rupinder Singh J. Paulo Davim, "Additive Manufacturing - Applications and Innovations" CRC Press Taylor & Francis Group, 2019 4. T. S. Srivatsan, T. S. Sudarshan, "Additive Manufacturing - Innovations, Advances, and Applications" CRC Press Taylor & Francis Group, 2016 5. Steinar Killi, "Additive Manufacturing - Design, Methods and Processes", Pan Stanford Publishing Ltd 2017 6. Larry Dosser , Kevin Hartke , Ron Jacobsen , Sarah Payne, "Additive manufacturing technology review - From prototyping to production: Additive Manufacturing Handbook", Routledge, 2017 7. Hwaiyu Geng, " Manufacturing Engineering Handbook", Second Edition, McGraw Hill, 2016 8. Bill Macy, " Reverse Engineering for Additive Manufacturing", Handbook of Manufacturing Engineering and Technology, Springer, 2014
Web References: 1. NPTEL IIT Madras, "Design for Additive Manufacturing", Prof. G. Saravana Kumar https://www.youtube.com/watch?v=gcia0aqZMf0 2. NPTEL IIT Guwahati, "Mathematical Modeling of Manufacturing Processes" Lecture 31 - Principle and development of additive manufacturing technologies-1, Prof. Swarup Bag 3. https://www.youtube.com/watch?v=7L42aRs68WI 4. NPTEL-NOC IITM, DFAM approach, "Simulation tools for AM, Design needs" mod06lec23 - Design for Additive manufacturing (DfAM) for Metal Printing, Mr. Vaman Kulkarni, Ex. Director Honeywell Technology, Bangalore; https://www.youtube.com/watch?v=I-0E-eiJdWk 5. NPTEL Course on Fundamentals of Additive Manufacturing Technologies by Prof. Sajan Kapil, IIT Guwahati, https://onlinecourses.nptel.ac.in/noc21_me115/preview

402014MJ: Additive Manufacturing System Design

Teaching Scheme	Credits	Examination Scheme
Theory : 04 Hr./Week	**04** Theory : 04	In-Semester : 30 Marks End-Semester : 70 Marks

Prerequisite Courses

Engineering Graphics, Solid Modelling and Drafting, Engineering Materials and Metallurgy, Additive Manufacturing Technology, Modelling Lab, Design for Additive Manufacturing

Course Objectives

1. To identify the AM System Equipment Topology/Layouts, Construction and Working.
2. To select the material based AM System.
3. To employ the AM Primary and Auxiliary System.
4. To analyze the AM Cell & Equipment Design.
5. To understand and evaluate the CAD Software and Controller Interfacing.
6. To determine the AM System Process Parameters for getting the desired performance level to build 3D parts and printer.

Course Outcomes

On completion of the course, learner will be able to

CO1. **CLASSIFY** the AM System Equipment Topology/Layouts, Construction and Working.
CO2. **ANALYZE** the material based AM System.
CO3. **DECIDE** the AM Primary and Auxiliary System.
CO4. **DESIGN** the AM Cell & Equipment for variety of applications.
CO5. **EVALUATE** the CAD Software and Controller Interfacing.
CO6. **PLAN** the AM System Process Parameters for getting the desired performance level to build 3D parts and printer.

Course Contents

Unit 1 Additive Manufacturing System Equipment Layouts

Construction and Working of Basic AM Machines - Classification of AM Processes and their respective System Equipment, 3D Positioning Systems (Gantry, Moving Bed, Deltabot, Spiderbot, etc.), Equipment Topology of Cartesian, Polar, SCARA, Delta, Articulated architecture, Sub-classification Rectilinear (XY, XZ, Crossed Heads) and Other types (Core XY, Belt, H-Bot, etc.), 3D Vs. 5D Printers, 3D-Rotoprinter, Flatpack 3D Printer, Advantages, Limitations and Applications

Types of Printing - 2D, 2.5D, 3D, 4D, 5D, 6D Printing and its applications

Equipment Frame Layout Designs - Serial Vs Parallel Topology, Moving Head Vs. Moving Bed, Top-down Vs. Bottom-up, Gantry Type, Delta, Box, A-Frame, C-Frame, F-Frame, H-Frame, L-frame, O-Frame, T-Frame, Inverted F L,T -Frame, 3D Printer Design Considerations, Frame Construction Methods

Unit 2 Material based Additive Manufacturing System

Polymer based Additive Manufacturing System

Filaments, Vat, Graduals Material Manipulation, Build Platform, Extruder Design (Direct Extruders Vs. Bowden Extruders), Extruder assemblies (cold Vs. hot end), Nozzles and their types (Stainless/Hardened Steel, Brass, Tungsten Carbide, Ruby nozzles, etc), Heated build/base platform, Heater types and Selection

Metal based Additive Manufacturing System

Wire, Graduals and Powder Material Manipulation, Build Platform

Laser Based System - Types of Laser (Solid-State, Gas, Liquid Dye, Semiconductor Diode, Fiber),

Laser Parameters, Continuous Vs. Pulsed Laser, Positioning Devices and Scanners System (galvanometer scanner)

Electron Beam System - Mechanism, Power supply, Electron Gun/Beam source (Tungsten (W) filament, Lanthanum Hexaboride (LaB6), and field-emission gun (FEG)), Optics and Positioning System (Electromagnetic lenses, Stigmators, Rasterizer), Vacuum Chambers (Vacuum Types and Pumping Systems, Chamber Types), Anode, and deflection coils

Binder Jetting System - Print Heads for ink delivery (piezoelectric Vs. thermal)

Unit 3 Additive Manufacturing Primary and Auxiliary System

Powder Production Processes - Atomization (Gas, Water, Centrifugal, Plasma), Melt Spinning, Rotating Electrode Process (Plasma REP), Mechanical Processes (Comminution, Mechanical Alloying), Chemical Processes (Oxide Reduction, Chloride Reduction, Hydrometallurgical Techniques, Carbonyl Reactions), Electrolysis

Powder Feeders - Classification (Mechanical wheel or screw powder feeder, Gravity-based, Fluidized bed and Vibrating types), Powder Delivery Nozzles (Lateral Vs. Coaxial), Powder Bed Delivery and Spreading Mechanisms (counter-rotating roller, wiper/Recoater, or doctor blade, Soft Vs. Hard Recoaters)

Wire Feed System - Classification (laser, arc welding and electron beam-based), Powder Delivery System (Lateral Vs. Coaxial)

Auxiliary Systems - Dispenser, Optical system, Laser/Beam Controller, Gas Filtration, Loading/unloading System, Moving Parts and end stops

Unit 4 AM Cell & Equipment Design

Design of Frames and Structures - Strength based Design Calculations, Nozzle Design, Bed/Build Plate Design, Arm-Spring Vibration Dampers, Belt Tension Mechanisms, Top/Bottom Panels, Frame Risers, Endcaps

AM Technology based Manipulation Design - Nozzle movement System, Bed Movement System, Selection of LM Rail/Guideways, Sockets, Recirculating Ball Screws, Recirculating ball carriage, Roller carriage, Linear and Rotary Bearings and Guideways, Timer Belt and Pulleys, Rollers and Brackets, Fixtures Design, Selection of Sensors, Actuators and Motors (DC/AC, Stepper and Servo, etc.)

Heating and Cooling System - Nozzle Heating for Raw material manipulation, Bed Heating to reduce warpage, Heater Selection, Heat Extracting Fans Selection, Inert Gas Cooling system, Gas Recirculation System,

Unit 5 CAD Software and Controller Interfacing

Slicing and Path Planning - Algorithm, Open-source/Commercial software, Pre-processing and Post-processing of AM Products, Procedures of 3D slicing and path planning, Use of Main and Support Material, Error Sources of CAD based data and Additive Manufacturing based product outputs

Software Integration - Single Printing Vs. Multi-printing Modes (traditional mode with slicing, revolving mode with slicing from the bottom-up, tangential mode for thin-wall sub-volume, normal mode, normal mode with slicing from the inside out), Topological Optimization Software for 3D Printing, Slicers & 3D Printer Hosts software, Relevant G/M Codes, Interpretation of codes generated by Slicing software, Standard Firmware, Control/Microcontroller Board used, Calibration

Unit 6 Additive Manufacturing System Process Parameters

Process Equipment - Product Design and Process Parameters, Governing Bonding Mechanism, Common faults and troubleshooting, Process Design, Material Characterization, Part shielding and Thermal management, Project planning, Operation and Maintenance, ASM/ASTM Standards,

In-process Sensing and Monitoring Technology - Sensors (Types and Function and selection), Process Parameters, Process Signatures, Part Quality Metrics, standard Powder/Filament/Wire/Vat

Characterization methods, Quality monitoring and inspection, Product Quality Bench-marking, Examples of commercially available in-situ monitoring systems

Books & Other Resources

Text Books

1. Evans, B., (2012), "Practical 3D Printers: The Science and Art of 3D Printing," Apress, ISBN-13: 9781430243922
2. Kelly, J. F., (2014), "3D printing : build your own 3D printer and print your own 3D objects," Que, ISBN-13: 9780789752352
3. Prusa, J., (2019), "Basics of 3D Printing,", prusa3d
4. Francis, A. K., (2014), "Make: 3D Printing: The Essentinal Guide to 3D Printers," Maker Media, ISBN-13: 9781457182938
5. Bell, C., (2015), "3D Printing with Delta Printers," Apress, ISBN-13: 9781484211748
6. Bandyopadhyay, A., Bose, S., (2021), "Additive Manufacturing," CRC Press, ISBN-13: 9781032238593
7. Aranda, S., (2022), "3D Printing Failures: How to Diagnose and Repair ALL Desktop 3D Printing Issues," SD3D.com
8. Toyserkani, E., Sarker, D., Ibhadode, O. O., Liravi, F., Russo, P., Taherkhani, K., (2022), "Metal Additive Manufacturing," Wiley, ISBN-13: 9781119210788
9. Yang, J., Na, L., Shi, J., Tang, W., Zhang, G., Zhang, F., "Multimaterial 3D Printing Technology," Academic Press, ISBN-13: 9780081029916
10. Mehta, N. K., (2017), "Machine Tool Design and Numerical Control," McGraw Hill Education, ISBN-13: 9781259004575

Reference Books

1. Patrick Hood-Daniel, P., Kelly, J. F., (2011), " Printing in Plastic: Build Your Own 3D Printer," Apress, ISBN-13: 9781430234449
2. Horvath, J., Cameron, R., (2020), "Mastering 3D Printing: A Guide to Modeling, Printing, and Prototyping," Apress, ISBN-13: 9781484258415
3. Yadroitsev, I., Yadroitsava, I., Du Plessis, A., MacDonald, E., (2021), "Fundamentals of Laser Powder Bed Fusion of Metals," Elsevier, ISBN-13: 9780128240908
4. Yan, C., Shi, Y., Zhaoqing, L., Wen, S., Wei, Q., (2021), "Selective Laser Sintering Additive Manufacturing Technology," Academic Press, ISBN-13: 9780081029930
5. Diegel, O., Nordin, A., Motte, D., (2020), "A Practical Guide to Design for Additive Manufacturing, Springer, ISBN-13: 978981138280-2
6. Redwood, B., Schöffer, F., Garret, B., (2017), "The 3D Printing Handbook: Technologies, design and applications, 3D Hubs, ISBN-13: 9789082748505
7. Gibson, I., Rosen, D., Stucker, B., Khorasani, M., (2021), "Additive Manufacturing Technologies," Springer, ISBN-13: 9783030561260
8. Jean-Claude, A., (2017, 2018), "From additive manufacturing to 3D/4D printing, Volume 1, 2 and 3, ISTE, ISBN-13: 9781786301192, 9781786301208, 9781786302328
9. Kumar, S., (2020), "Additive Manufacturing Processes," Springer, ISBN-13: 9783030450885
10. Killi, S. W., (2017), "Additive Manufacturing: Design, Methods, and Processes," Pan Stanford Publishing, ISBN-13: 9789814774161

402015MJ: 3D Printing Lab

Teaching Scheme	Credits	Examination Scheme
Practical : 02 Hr./Week	Practical : 01	Term Work : 50 Marks

Prerequisite Courses

Engineering Graphics, Solid Modelling and Drafting, Engineering Materials and Metallurgy, Digital Manufacturing Laboratory, Additive Manufacturing Technology, Modelling Lab, Design for Additive Manufacturing, Additive Manufacturing System Design

Course Objectives

1. To identify the AM System Equipment Topology/Layouts, Construction and Working.
2. To select the material based AM System.
3. To understand and evaluate the AM Primary and Auxiliary System, the CAD Software and Controller Interfacing.
4. To determine the AM System Process Parameters for getting the desired performance level to build 3D parts and printer.

Course Outcomes

On completion of the course, learner will be able to

CO1. **DISTINGUISH** AM System Equipment Topology/Layouts, Construction and Working.
CO2. **COMPARE** the material based AM System.
CO3. **EVALUATE** the AM Primary and Auxiliary System.
CO4. **DEVELOPE** the AM Cell & Equipment for variety of applications.
CO5. **SELECT** the CAD Software and Controller Interfacing.
CO6. **PREDICT** the AM System Process Parameters for getting the desired performance level to build 3D parts and printer.

Guidelines for Laboratory Conduction

The student shall complete the following activity as a Term Work

The learner shall complete minimum 10 of the following activities as a Term-Work:

List of Practical *(Select any Four Practical from Practical # 1, 3 to 7;, Practical # 2,8,9 and 10 are Mandatory)*

1. To study and Survey of existing 3D Printer/Equipment Topology and Layout (Cartesian, Polar, SCARA, Delta Articulated architecture).
2. Dis-assembly and Assembly of any two off-the shelf Do-it-yourself desktop 3D Printers Kits of different topology.
3. To study and Survey of Polymer Extrusion based FDM/FFF Additive Manufacturing System.
4. To study and Survey of Polymer/Metal based SLA/SLM/DMLS Additive Manufacturing System.
5. To study and Survey of Laser Based/ Electron Beam System and its sub-systems and Applications.
6. To study and Survey of Binder Jetting System and its sub-systems and Applications
7. Survey and Design of Heating and Cooling System required for FFF/FDM 3D Printers.
8. Survey and Design of AM Technology based Manipulation Design of Nozzle movement System and Bed Movement System.
9. Investigation of in-fill and slicing and printing strategy on final 3D Printed Product and its comparison with same CAD file using Topological Optimization Software.
10. Take any one Product containing minimum 5 parts excluding standard brought out items. Apply DfAM on that product parts using the principals of Additive Manufacturing. Start with

modelling CAD file and Convert it into *.stl file. Using slicing Software convert it into G/M Code and get it 3D Printed using different types of In-fill, slicing, single and multi-printing modes. Finally assemble the product. Make Detailed Report containing concept, CAD (2D, Trimetric Drawing/Isometric and Exploded View along with Dimensions, GD&T.

List of Industrial Visits *(Select any Two Industrial Visits from Practical # 11 to 13)*

11. Industrial Visit to Any Application based Polymer 3D Printing Facility.
12. Industrial Visit to Any Application based Metal 3D Printing Facility.
13. Industrial Visit to Additive Manufacturing Machine Plant.

Instructions for Laboratory Conduction

Please note following instructions regarding Laboratory Conduction:

- The student shall complete the following hands-on activities as a Term Work under the guidance of concerned Teaching **Faculty** member.
- The open source software shall be preferred for conduction of practical.
- Industrial Visits to be conducted by the Teaching **Faculty** (subject Teacher).
- Demonstration of **Topology based varieties of 3D Printers** to be taught by a **subject Teacher in Practical slot**.

Industrial Visits

Visit to any Additive Manufacturing Machine Plant/Application based AM Printing Facility.
The visit report consists of

- Details about the Industry/Process Plant.
- Operational description of the Equipment with specification, its use, capacity, application etc.

402016MJ: 3D Printing Applications & Entrepreneurship

Teaching Scheme	Credits	Examination Scheme
Theory : 04 Hr./Week	**04** Theory : 04	In-Semester : 30 Marks End-Semester : 70 Marks

Prerequisite Courses

Engineering Graphics, Solid Modelling and Drafting, Engineering Materials and Metallurgy, Additive Manufacturing Technology, Modelling Lab, Design for Additive Manufacturing, Additive Manufacturing System Design

Course Objectives

1. To introduce the Design requirements, Approaches and Strategies for implementation of AM at small/industrial scale.
2. To understand the Requirements, Approaches, Technologies and Applications of AM in Aerospace, Energy, Machine-Tools and Transportation Applications.
3. To understand the Requirements, Approaches, Technologies and Applications of AM in Biomedical and Health-Care Applications.
4. To understand the Requirements, Approaches, Technologies and Applications of AM in Consumer Product Applications.
5. To understand the Requirements, Approaches, Technologies and Applications of AM in Art, History, Archeology, Entertainment, Architecture and Landscaping Applications.
6. To undertake the Product Design, Innovation, Bench-Marking and Entrepreneurship.

Course Outcomes

On completion of the course, learner will be able to

CO1. **APPLY** the Design requirements, Approaches and Strategies for implementation of AM at small/industrial scale.

CO2. **ANALYZE** and ADAPT the Requirements, Approaches, Technologies and Applications of AM in Aerospace, Energy, Machine-Tools and Transportation Applications.

CO3. **ANALYZE** and ADAPT the Requirements, Approaches, Technologies and Applications of AM in Biomedical and Health-Care Applications.

CO4. **ANALYZE** and ADAPT the Requirements, Approaches, Technologies and Applications of AM in Consumer Product Applications.

CO5. **ANALYZE** and ADAPT the Requirements, Approaches, Technologies and Applications of AM in History, Archeology, Entertainment, Architecture and Landscaping Applications.

CO6. **CREATE** the Product Designs, Innovations and ADAPT the Bench-Marking and Certification to DEVELOPE Entrepreneurs.

Course Contents

Unit 1 Industrial and Small-Scale Implementation of Additive Manufacturing

Introduction - Transition from the traditional "design for manufacturing" model to a new paradigm of "manufacturing by design", Application of Additive Technologies for Industrial Products, Direct part fabrication in Engineering Thermoplastics, Metals and Composites, Approaches to Indirectly Manufacturing Parts, New material and New Trends in Additive Manufacturing, Material and Process Selection, Potentials and Resulting Perspectives (Complex Geometries, Integrated Geometry, Integrated Functionalities, Multi-Material Parts and Graded Materials)

Approaches and Strategies - Approaches (CAD Verification Models for Aesthetics and proof-of-concept Models, Functional Prototyping, Direct Digital Production of End-Use Parts, Investment Casting, Indirect Manufacturing and Tooling, Topological Optimization, Part Consolidation, Part Integration, Remanufacturing and Repair, etc.), Customization (Customized Mass Production - One-

Offs and Small Batch Production, Individualization, Personalization), Personal Fabrication, Self-Customization, Distributed Customized Production - Coproducing

Design Requirements - Process aspects of design (Part performance, quality, evaluation, Post processing), Cost Analysis, Product and process design tools (AM Design Software and Process Software), Cellular Structure Design (Foam, Honeycomb, Lattice, Hybris, etc.), Support Structure Design, Design of Fixtures, Jigs, and Tooling, Test Specimen Design, Prototype Design, Hybrid Design

Unit 2 Aerospace, Energy, Machine-Tools and Transportation Applications

Introduction - Functional, Manufacturing and Commercial requirements of Aerospace, Energy, Machine-Tools and Transportation Technology, Functional CAD modeling and customized part manufacturing, Materials and their requirements, Additive manufacturing fabrication of various types of materials, Functionally graded material (FGMs) and its applications, Advantages, Disadvantages, Limitations and Challenges of AM in Aerospace, Machine-Tools, Transportation Technology and other Product/Process based Industries (Chemical/Petroleum/Energy/Electronic/Sensor & Transducer/Mechatronic Sectors)

Approaches and Technologies - Approaches (Low-cost systems, Low-mass (lightweight) systems, Advanced propulsion, In Situ Resource Utilization (ISRU), Design requirements, Manufacturing capabilities and benefits), Comparison of different additive manufacturing technologies used for distinct applications and parameters, Airworthiness, Crashworthiness

Applications - Challenges, opportunities and potential future applications & examples like Automotive, Aerospace, Turbomachinery, Machine-Tools, Experimental Performance Wind Tunnel/CFD Testing/Evaluation, Transportation Technology, Defense Products, Chemical/Petroleum/Energy Technology, Robotics and Automation Components, Electronic/ Sensor & Transducer/ Mechatronic Sectors

Unit 3 Biomedical and Health-Care Applications

Introduction - Functional, Manufacturing and Commercial requirements of Health-Care, Personalized Surgery, Biomedical Applications, Prosthetics, Orthotics, Deontic, etc., Medical modeling and customized implants for human appendage/bone damaged or lost during accidents or absent at birth, Steps involves to fabricate 3D medical models, Biomedical/Biocompatible/Biomaterials/ Biodegradable Materials, Mechanical Properties and their Applications, Functionally graded material (FGMs) and its applications, Nanomaterials for 2D/3D Printing, Comparison of different additive manufacturing g technologies of bio printing on distinct parameters, Advantages, Disadvantages, Limitations and Challenges of AM in Biomedical and Health-Care Applications, Post-processing

Bio-printing, Tissue and Organ Engineering - Functional and Commercial requirements of Bio-organ engineering, Inkjet Printing, Photolithography and Two Photon Polymerization, Direct Laser Printing, Extrusion Printing (Cell-Laden Printing, Direct Cell Printing/Self-assembly, Direct Cell Printing of Macrovascular Constructs), Bioinks (with Cell Encapsulation, with Cell Aggregates/Pellets, Spheroids), Biomaterial Inks (Synthetic Hydrogels, Thermoplastics and Resins, Ceramics, etc.), Application of 2D/2.5D/3D/4D/5D/6D Printing

Applications - Examples of applications of 3D printing in medical field like Bio printing Tissues and Organs, Surgical tools, Lifelike human models with functional organs capable of intelligent sensor feedback and anatomical models for pre-surgical planning and preparation, Custom-made implants and Body parts/mirror replica including Orthopaedic Oncology/Cranio-maxillo-facial/Extremities, Custom-made prosthetics, Dentistry application, Orthotics, Medical custom Products, Bio-printing, scaffolds and Tissue Engineering, Clinical applications in traumatology and orthopedics, Pharmaceuticals, Drug Delivery, Medical Devices, Physiotherapy Aids.

Unit 4 Consumer Product Applications

Introduction - Principle of Social Manufacturing, Mass Vs. Class Customization, Functional, Manufacturing and Commercial requirements of Consumer Product Applications, Functional CAD modeling and customized Consumer Product manufacturing, Ergonomic Design Considerations, Design Flexibility, Operational Productivity, Materials and their requirements, End-Use Performance with Production-Grade Materials, Additive manufacturing fabrication of various types of materials, Advantages, Disadvantages, Limitations and Challenges to managing AM operations in the consumer goods industry, Future trends based on Product/Process based Consumer Products

Applications - Examples of applications of 3D printing in Consumer Products field like Eye wares, Sporting Goods, Footware, Home and Office utilities, Lighting Utilities, Leisure Products, Entertainment Products and Appliances, Kitchen Wares, Backpacking Equipment, Foods and Beverages Processing, Make up and Toiletries

Unit 5 Art, History, Archeology, Entertainment, Architecture and Landscaping

Introduction - Art to Part Concept, Expression of Creativity, Functional, Aesthetics, Ergonomics, Manufacturing and Commercial requirements of Types of Creative Art Expressions, Types of Jewelry (Indian/Middle-East/Western, Fusion, Pavé and Stone Setting) and their functional and manufacturing requirements, Digital Jewelry Manufacturing Workflow, Functional CAD modeling and customized Creative Art Expressions, Precious/Non-conventional/look alike lightweight Materials and their requirements, Additive manufacturing technologies used in Creative Art Expressions, Advantages, Disadvantages, Limitations and Challenges of AM in Creative Art Expressions

Approaches and Technologies - Lost wax Casting, Mold Making, Complex Master Patterns, Prototyping for fast design iteration, validation, stone settings, and try-on, Casting and Rubber molding patterns, Wax 3D Printing Solutions (Wax Pattern, Master Pattern, Rubber Mold Making and Wax Injection, etc.)

Applications - Examples of applications of 3D printing in Art, History, Archeology, Architecture and Landscaping field like Home utilities, Mass Scale and Custom made Jewelry/Ornaments Products, Archeology, Architecture and Landscaping, Entertainment Industry Applications

Unit 6 Product Design, Innovation, Bench-Marking and Entrepreneurship

Introduction - Rapid Prototyping Process Evaluation based on Quality, Quantity, Accuracy, Finishes, Functionality, Aesthetics, Ergonomics, Artistry, Flexibility, Primary and Secondary Operations, Functional Materials, Support Materials, Time, Speed, Cost, Strengths and Constraints, Factory Set-up and Layouts, Product and Process Planning, Conventional Vs. Integrated Design Approach, Design by Composition, Part Decomposition and Assembly-based Redesign for Additive Manufacturing, Design for Modularity (DFMo), Design for Manufacturing and Assembly (DFMA), Innovative Designs, Reverse Engineering, Sustainable Additive Manufacturing ecosystem, Significant application areas to help improve environmental sustainability of AM Applications

Bench-Marking - Product Development Process, Design Specifications and Necessity for benchmarking, Internal Bench-marking, Competitive Bench-marking, Generic Bench-marking, Competitive Benchmarking, Industry Qualification, Standards, Quality Control, and Measurement Sciences in 3D Printing and Additive Manufacturing, Certification Approaches and Agencies, Socio-Legal, Philosophical and Economic Aspect of 3D Printing

Entrepreneurship - Manufacturer-centric Vs. Consumer-centric Business models, Introduction to Entrepreneurship, Current Approach of Manufacturing Enterprises, Digiproneurship, New Types of Products and Employment Opportunities, Digiproneurship Research and Development priorities for Additive Manufacturing, National/International/Government/Private Funding Agencies, Crowd-Funding, Start-up Stories

Books & Other Resources

Text Books

1. Bandyopadhyay, A., Bose, S., (2021), "Additive Manufacturing," CRC Press, ISBN-13: 9781032238593
2. Muralidhara, H. B., Banerjee, S., (2022), "3D Printing Technology and Its Diverse Applications," Apple Academic Press, ISBN-13: 9781771889780
3. Gebhardt, A., Hötter, J-S., (2016), "Additive Manufacturing. 3D Printing for Prototyping and Manufacturing," Carl Hanser Verlag, ISBN-13: 9781569905821
4. Lipson, H., Kurman, M., (2013), "Fabricated: The New World of 3D Printing," Wiley, ISBN-13: 9781118350638
5. Froes, F. H., Boyer, R., (2019), "Additive Manufacturing for the Aerospace Industry," Elsevier, ISBN-13: 9780128140628
6. Froes, F. H., Qian, M., Niinomi, M., (2019), "Titanium for Consumer Applications: Real-World Use of Titanium," Elsevier, ISBN-13: 9780128158203
7. Tarancón, A., Vincenzo Esposito, V., (2021), "3D Printing for Energy Applications," Wiley-American Ceramic Society, ISBN-13: 9781119560753
8. Gibson, I., (2005), "Advanced Manufacturing Technology for Medical Applications: Reverse Engineering, Software Conversion and Rapid Prototyping," Wiley, ISBN-13: 9780470016886
9. Ovsianikov, A., Yoo, J., Mironov, V., (2018), "3D Printing and Biofabrication," Springer, ISBN-13: 9783319454436
10. Hoskins, S., (2018), "3D Printing for Artists, Designers and Makers," Bloomsbury Visual Arts, ISBN-13: 9781474248679
11. Perrot, Arnaud, (2019), "3D printing of concrete : state of the art and challenges of the digital construction revolution," ISTE, ISBN-13: 9781786303417
12. Godoi, F. C. Bhandari, B. R., Prakash, S., Zhang, M., (2019), "Fundamentals of 3D food printing and applications," Academic Press, ISBN-13: 9780128145647
13. Milewski, J. O., (2017), "Additive Manufacturing of Metal: From Fundamental Technology to Rocket Nozzles, Medical Implants, and Custom Jewelry," Springer, ISBN-13: 9783319582047
14. Yang, J., Na, L., Shi, J., Tang, W., Zhang, G., Zhang, F., "Multimaterial 3D Printing Technology," Academic Press, ISBN-13: 9780081029916
15. Kamrani, A. K., Nasr, E. A., (2014), "Engineering Design and Rapid Prototyping," Springer, ISBN-13: 9781489989918
16. Raja, V., Fernandes, K. J., (2008), "Reverse Engineering: An Industrial Perspective," Springer, ISBN-13: 9781846288555
17. Chua, C. K., Wong, C. H., Yeong, W. Y., (2017), "Standards, Quality Control, and Measurement Sciences in 3D Printing and Additive Manufacturing," Academic Press, ISBN-13: 9780128134894
18. van den Berg, B., van der Hof, S., Kosta, E., (2016), "3D Printing: Legal, Philosophical and Economic Dimensions," T.M.C. Asser Press, ISBN-13: 9789462650954

Reference Books

1. Gibson, I., Rosen, D., Stucker, B., Khorasani, M., (2021), "Additive Manufacturing Technologies," Springer, ISBN-13: 9783030561260
2. Miltiadis A. Boboulos, M. A., (2010), "CAD-CAM & Rapid Prototyping Application Evaluation," Ventus Publishing ApS, ISBN-13: 9788776816766
3. Farooqi, K. M., (2017), "Rapid Prototyping in Cardiac Disease: 3D Printing the Heart," Springer,
4. Khan, M. A., Winowlin Jappes, J. T., (2022), "Innovations in Additive Manufacturing," Springer, ISBN13: 9783030894009
5. Ovsianikov, A., Yoo, J., Vladimir Mironov, V., (2018), "3D Printing and Biofabrication," Springer, ISBN-13: 9783319454436

6. Gebhardt, A., (2012), “Understanding Additive Manufacturing: Rapid Prototyping, Rapid Tooling, Rapid Manufacturing,” Hanser Publishers, ISBN-13: 9781569905074
7. Daly, A., (2016), “Socio-Legal Aspects of the 3D Printing Revolution,” Palgrave Macmillan, ISBN-13: 9781137515551
8. Kalaskar, D. M., (2017), “3D Printing in Medicine,” Woodhead Publishing, ISBN-13: 9780081007174
9. Rybicki, F. J., Grant, G. T., (2017), “3D Printing in Medicine: A Practical Guide for Medical Professionals,” Springer, ISBN-13: 9783319619224
10. van Wijk, A., van Wijk, I., (2015), “3D Printing with Biomaterials: Towards a Sustainable and Circular Economy,” IOS Press, ISBN-13: 9781614994855
11. Piqué, A., Serra, P., (2018), “Laser Printing of Functional Materials: 3D Microfabrication, Electronics and Biomedicine, Wiley-VCH, ISBN-13: 9783527342129
12. Rael, R., Fratello, V. S., (2018), “Printing Architecture: Innovative Recipes for 3D Printing,” Princeton Architectural Press, ISBN-13: 9781616896966
13. Maniruzzaman, M., (2019), “3D and 4D printing in Biomedical Applications: Process Engineering and Additive Manufacturing,” Wiley-VCH, ISBN-13: 9783527344437
14. Anandharamakrishnan, C., Moses, J. A., Anukiruthika, T., (2022), “3D Printing of Foods,” Wiley, ISBN-13: 9781119669821
15. Devine, D. M., (2019), “Polymer-Based Additive Manufacturing: Biomedical Applications,” Springer, ISBN-13: 9783030245313
16. McMills, A. E., (2018), “3D Printing Basics for Entertainment Design,” Routledge, ISBN-13: 9781138211346
17. Bañón,C., Raspall, F., (2021), “3D Printing Architecture: Workflows, Applications, and Trends,” Springer, ISBN-13: 9789811583872
18. Binnard, M., (2012), “Design by Composition for Rapid Prototyping,” Springer, ISBN-13: 9781461374008

402017MJ - Seminar

Teaching Scheme	Credits	Examination Scheme
Practical : 02 Hr./Week	Practical : 01	Term Work : 50 Marks

Prerequisite Courses

Engineering Graphics, Solid Modelling and Drafting, Project Based Learning, Digital Manufacturing Laboratory, Additive Manufacturing Technology, Modelling Lab, Design for Additive Manufacturing, Additive Manufacturing System Design, 3D Printing Lab, 3D Printing Applications & Entrepreneurship,

Course Objectives

1. Identify and compare technical and practical issues related to the area of course specialization.
2. Outline annotated bibliography of research demonstrating scholarly skills.
3. Prepare a well-organized report employing elements of technical writing and critical thinking.
4. Demonstrate the ability to describe, interpret and analyze technical issues and develop competence in presenting.

Course Outcomes

On completion of the course, learner will be able to

CO1. ESTABLISH motivation for any topic of interest and DEVELOP a thought process for technical presentation.
CO2. ORGANIZE a detailed literature survey and BUILD a document with respect to technical publications.
CO3. ANALYSIS and COMPREHENSION of proof-of-concept and related data.
CO4. EFFECTIVE PRESENTATION and IMPROVE soft skills.
CO5. MAKE use of new and recent technology (e.g. Latex) for creating technical reports.

Course Contents

The evaluation of the Seminar is proposed with the following stages.

Stage-I In this stage the student is expected to deliver the following:

1. Topic selection
2. Literature review
3. State of the art related to the topic of interest

Stage-II

1. Problem Statement
2. Methodology
3. Scope and Objectives

Note

- A review of the student's progress should be made after In-Sem examination, within a week.
- During this Review, the student is expected to complete Stage-1 and Stage-II.

Stage-III

1. Quantification of Results
2. Concluding Remarks or Summary

Stage-IV

1. Final Report

2. Final Presentation/Viva

Note

- The final Presentation/Viva will be assessed by a Committee including an Expert (preferably from Industry with minimum 5 years of experience) and an Internal Panel. The Internal Panel will consist of the Seminar Guide and two Subject Experts, approved by the HOD and the Principal of the Institute.
- Examination schedule will be prepared at Institute level (and not at University level), though it is under Term Work head. The appointment of the Internal Panel and the External (Industrial) Expert will be taken care by the respective Institute. The Seminar Presentation will be held after the term-end and before University External Viva.

Contents of the Seminar Report

The contents of the Seminar Report are expected to include the following:

- Abstract/Summary
- Introduction - Scope and Methodology
- Literature review - The review should be conducted from at minimum five research papers published during last five year.
- Case study - Critical Analysis and Evaluation, if possible Simulation and finally Validation.
- References