VEERMATA JIJABAI TECHNOLOGICAL INSTITUTE
**(VJTI)**
MATUNGA, MUMBAI 400 019

(Autonomous Institute affiliated to University of Mumbai)

Curriculum
(Scheme of Instruction & Evaluation and Course contents)

For
Graduate Programme Leading to
Honours / Minor Degree
in
Smart Manufacturing

VEERMATA JIJABAI TECHNOLOGICAL INSTITUTE

(Autonomous Institute affiliated to University of Mumbai)

Curriculum

(Scheme of Instruction & Evaluation and Course contents)

For

Honours / Minor Degree

in

Smart Manufacturing

**Scheme Rules**
**Honours / Minor Degree Program Structure**

| Title of Program | Honours / Minor Degree |
|---|---|
| Eligibility & Progression | 1. Third year undergraduate engineering students with minimum CPI of 7.0 and no course backlog at the end of semester 4.<br>2. It is optional for students to take Honours / Minor degree program.<br>3. An eligible student can opt for either Honours or Minors program.<br>4. Failure in the courses of honours / minor program head shall not be counted for candidate's progression for next academic year. |
| No. of years/Semesters: | 4 Semesters (5th, 6th, 7th and 8th) |
| Credits: | 18 Credits earned shall be over and above the minimum credits required for earning a BTech degree. These credits shall not be included in the SPI / CPI scores of the student. |
| To be implemented from Academic Year: | AY 2022-23<br>(Applicable for third year, semester V, BTech students) |

**B. Tech Honours Degree**
Honours is an additional credential a student earns if the student opts for the extra 18 credits needed for this in her / his own discipline. The concerned department specifies the course requirements for earning the Honours. An Honours is similar to a specialisation in the student's own discipline.

Honour courses are either advanced level courses in the student's discipline or are courses designed to give a student more exposure to specific area(s) of the student's discipline. On successful accumulation of credits at the end of the B.Tech. programme, a separate grade sheet will be issued by the Examination Section after completion of the BTech program. The Degree Certificate of the student also will indicate "Bachelor of Technology in XXX* , with honours in Internet of Things. No SPI or CPI will be calculated for honours degree courses. Any backlog courses with respect to Honours Degree should be successfully completed by the BTech semester VIII re-examination. If the student fails to earn 18 credits even after BTech semester VIII re-examination, no certificate for completion of Honours Degree will be given, instead the student will get a certificate stating completion of extra courses.

**BTech with a Minor Degree**
A Minor is an additional credential, a student earns if the student opts for earning 18 credits worth of additional learning in a discipline other than student's major discipline. The concerned department specifies the course requirements for earning a Minor Degree in a particular area.

The Department offering a Minor degree prescribes a specific set of courses and/ or other activities like projects for earning a minor in that discipline. On successful accumulation of credits at the end of the B.Tech. programme, a separate grade sheet will be issued by the Examination Section after completion of the BTech program. The Degree Certificate of the student also will indicate "Bachelor of Technology in YYY@ , with Minor in Internet of Things." No SPI or CPI will be calculated for Minor degree courses. Any backlog courses with respect to Minor Degree should be successfully completed by the BTech semester VIII re-examination. If the student fails to earn 18 credits even after BTech semester VIII re-examination, no certificate for completion of Minor Degree will be given, instead the student will get a certificate stating completion of extra courses.

Content delivery, curriculum and exams will remain same for both Honours and Minor degree. Short listing of students for honours and minor degrees will be done on basis of CPI of semester 4.

Additional Degree: Internet of Things will be honours and minor degree for Major Degree students as follows:

| Honours Degree [*] | Minor Degree[@] |
|---|---|
| BTech Civil Engineering | BTech Electronics Engineering |
| BTech Mechanical Engineering | BTech Electronics & Telecommunication Engineering |
| BTech Textile Technology | BTech Electrical Engineering |
| | BTech Computer Engineering |
| | BTech Information Technology |

## Scheme of Instruction and Evaluation

| | Minor Smart Manufacturing | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|
| Scheme of Instruction | | | | | Scheme of Evaluation | | | | |
| **S. No.** | **Course Code** | **Course Title** | **L-T-P (Hours/week)** | **Credits** | **Semester** | **TA** | **MST** | **ESE** | **ESE hours** |
| 1. | SM3001T | Optimization Techniques | 3-1-0=4 | 4 | V | 20 | 20 | 60 | 3 |
| 2. | SM3002T | Additive Manufacturing | 3-0-0=3 | 3 | VI | 20 | 20 | 60 | 3 |
| 3. | SM3002P | Additive Manufacturing Lab | 0-0-0=2 | 1 | VI | 60 | - | 40 | - |
| 4. | SM4001T | Industry 4.0 and IIoT | 3-1-0=4 | 4 | VII | 20 | 20 | 60 | 3 |
| 5, | SM4901D | Mini-project | 0-0-4=4 | 2 | VIII | 60 | - | 40 | - |
| 6. | SM4002T | Design for Additive Manufacturing | 3-0-0=3 | 3 | VIII | 20 | 20 | 60 | 3 |
| 7. | SM4002P | Design for Additive Laboratory | 0-0-0=2 | 1 | VIII | 60 | - | 40 | - |

| | |
|---|---|
| **Programme Name** | **Honors/Minor Smart Manufacturing, Semester-V** |
| **Course Code** | **SM3001T** |
| **Course Title** | **Optimization Techniques** |

## COURSE OUTCOMES

After completion of course, students would be able to:

1. Classify and differentiate problem solving methods and tools of optimization.
2. Formulate an optimization problem to solve using evolutionary computing methods.
3. Design and implement GA, PSO and ACO algorithms for optimization problems in Mechanical Engineering. \
4. Apply soft computing techniques for design, control and optimization of Manufacturing systems.

## COURSE CONTENT

| | |
|---|---|
| **Module I** | **Introduction** |
| | **Problem Solving Methods and Tools:** Problem Space, Problem solving, State space, Algorithm's performance and complexity, Search Algorithms, Depth first search method, Breadth first search methods their comparison |
| **Module II** | **Evolutionary Computing Methods:** |
| | Principles of Evolutionary Processes and genetics, A history of Evolutionary computation and introduction to evolutionary algorithms, Genetic algorithms, Evolutionary strategy, Evolutionary programming, Genetic programming. |
| **Module III** | **Genetic Algorithm and Genetic Programming:** |
| | Basic concepts, working principle, procedures of GA, flow chart of GA, Genetic representations, (encoding) Initialization and selection, Genetic operators, Mutation, Generational Cycle, applications. |
| **Module IV** | **Swarm Optimization:** |
| | Introduction to Swarm intelligence, Ant colony optimization (ACO), Particle swarm optimization (PSO), Artificial Bee colony algorithm (ABC), Other variants of swarm intelligence algorithms. |
| **Module V** | **Advances in Soft Computing Tools:** |
| | Fuzzy Logic, Theory and applications, Fuzzy Neural networks, Pattern Recognition, Differential Evolution, Data Mining Concepts, Applications of above algorithms in manufacturing engineering problems. |
| **Module VI** | **Deep Neural Networks:** |
| | Neuron, Nerve structure and synapse, Artificial Neuron and its model, activation functions, Neural network architecture: single layer and multilayer feed forward networks, recurrent networks. Back propagation algorithm, factors affecting back propagation training, applications. |
| **Module VII** | **Application of optimization to Mechanical Engineering/Production Engineering Problems:** |
| | Application to Inventory control, Scheduling problems, Production, Distribution, Routing, Transportation, Assignment problems etc. |

| | |
|---|---|
| | **TEXT BOOKS:** |
| **1** | Soft Computing Integrating Evolutionary, Neural and Fuzzy Systems, Tettamanzi Andrea, Tomassini and Marco, Springer, 2001. |
| **2** | Artificial Intelligence, Elaine Rich, McGraw Hill, 2/e, 1990. |
| **3.** | Multi-objective Optimization using Evolutionary Algorithms, Kalyanmoy Deb, John Wiley and Sons, 2001. |

| | |
|---|---|
| **4.** | Optimization for Engineering Design: Algorithms and Examples, Kalyanmoy Deb, PHI, Ltd, 2012 |

| | |
|---|---|
| **Programme Name** | **Honors/Minor Smart Manufacturing Semester-VI** |
| **Course Code** | **SM3002T** |
| **Course Title** | **Additive Manufacturing** |

**COURSE OUTCOMES**

After completion of course, students would be able:

1. To understand and evaluate various existing Product Development processes
2. To develop new technologies in the field Rapid Prototyping & Manufacturing
3. To generate innovative ideas to reduce time and cost by developing new methods and materials for the modern manufacturing industry.

**COURSE CONTENTS**

| | |
|---|---|
| **Module I** | **Introduction** |
| | Product Developing Cycle, Definition of Rapid Product Development, Virtual prototypical and rapid manufacturing technologies, Physical Prototyping & rapid manufacturing technologies, Synergic integration technologies |
| **Module II** | **Additive Manufacturing Processes** |
| | Principal of Rapid Prototyping or Additive Manufacturing, Various RP (AM) technologies, Selection of a suitable RP process for a given application, Status of outstanding issue in RP- accuracy, speed, materials (strength, homogeneity and isotropy), Emerging Trends. 5.Applications and Case Studies: Engineering Applications, Medical Applications |
| **Module III** | **Rapid Tooling** |
| | Introduction to Rapid Tooling, Indirect Rapid Tooling Processes, Direct Rapid Tooling Processes, Emerging Trends in Rapid Tooling |
| **Module IV** | **Rapid Manufacturing** |
| | Definition of Rapid Manufacturing, Roadmap to Rapid Manufacturing, Comparison of Various Processes for Rapid Manufacturing of Metallic Objects, Rapid Manufacturing of Polymeric Objects, Rapid Casting, other RM Processes like Hybrid Layered Manufacturing, Material Translation using Segmented Object Manufacturing. |
| **Module V** | **Reverse Engineering** |
| | Need for Reverse Engineering, Digitizing Methods and its Principles, Types measurements, Contact & Non-contact Types, Coordinate Measuring Machine (CMM),Capture devices, Sensors, Scanning Methods, Data representation, Data processing and manipulation techniques. Applications |
| **Module VI** | **Processing of Polyhedral Data** |
| | Processing of Polyhedral Data: Polyhedral BRep modeling, Introduction to STL format, Defects and repair of STL files, Overview of the algorithms required for RP&T and Reverse Engineering |

| | |
|---|---|
| | **TEXT BOOKS:** |
| **1.** | Rapid Product Development & Manufacturing, by K.P.Karunakaran, IIT, Bombay, 1st edition, 2013. |
| **2.** | Rapid Prototyping Principles and Applications by Rafiq Noorani, John Wiley & Sons - 1st edition, 2006. |
| **3.** | Virtual Reality by Ken Pimentel, Kevin Teixeira, Windcrest McGraw-Hill, 1st Edition, 2003. |
| | |

| | **ADDITIONAL READING:** |
|---|---|
| **1.** | User's Guide to Rapid Prototyping, By Todd Grimm, Society of Manufacturing Engineers, 1st edition, 2004 |
| **2.** | Rapid Prototyping: Principles and Applications in Manufacturing, Chua Chee Kai and Leong Kah Fai, John Wiley & Sons, 1997. |
| **3.** | Stereo-lithography and Other RP&M Technologies: from Rapid Prototyping to Rapid Tooling by Paul F. Jacobs, SME/ASME, 1996. |
| **4.** | Rapid Tooling: Technologies and Industrial Applications by Peter D. Hilton and Paul F. Jacobs (Editors.), Marcel Dekker. 4th edition, 2000. |
| **5.** | Rapid Prototyping by Andreas Gebharatdt, Hanser Publishers, 2nd edition – 2003. |
| **6.** | Rapid Manufacturing , An Industrial Revolution for the digital age by N.Hopkinson, R.J.M.Hague -2nd edition, 2006. |
| **7.** | Garage Virtual Reality by Linda Jacobson, Sams Publishing, 1994. |
| **8.** | Virtual Reality Systems by John Vince, Addison-Wesley. 1995. |

| | |
|---|---|
| **Programme Name** | **Honors/Minor Smart Manufacturing , SEMESTER - VI** |
| **Course Code** | **SM3002P** |
| **Course Title** | **Additive Manufacturing Lab** |

**COURSE OUTCOMES**

After completion of course, students would be able:

1. To develop 3D models, assemblies
2. To process ‘STL’ files from 3D models
3. To build rapid prototyping parts using FDM process
4. To apply surface finish enhancement techniques on FDM parts.

**List of Experiments:**

1. Development of 2D sketches using CAD/CAM/CAE Software
2. Development of 3D models using CAD/CAM/CAE software
3. Development of 3D assembly models using CAD/CAM/CAE Software
4. Processing of STL files of 3D modelled parts/assemblies
5. Building Rapid Prototyping (FDM) parts/assemblies
6. Applying post processing techniques on Rapid Prototyping (FDM) parts
7. Surface roughness measurement of FDM parts.

| | |
|---|---|
| **Programme Name** | **Honors/Minor Smart Manufacturing Semester-VII** |
| **Course Code** | **SM4001T** |
| **Course Title** | **Industry 4.0 and IIoT** |

## COURSE OUTCOMES

After completion of course, students would be able:

1. Understand key concepts of Industry 4.0
2. Understand the drivers and enablers of Industry 4.o
3. Learn about various IIoT-related protocols
4. Build simple IIoT Systems using Arduino and Raspberry Pi

## COURSE CONTENT

| | |
|---|---|
| **Module I** | **Fundamentals of Industry 4.0:** |
| | Industry 4.0: Globalization and Emerging Issues, The Fourth Revolution, Lean Production Systems, Mass Customization, Smart and Connected Business Perspective, Smart Factories, Industry 4.0: Cyber Physical Systems and Next Generation Sensors, Collaborative Platform and Product Lifecycle Management, Augmented Reality and Virtual Reality, Artificial Intelligence, Big Data and Advanced Analysis |
| **Module II** | **Introduction to IIoT:** |
| | Architectural Overview, Design principles and needed capabilities, IoT Applications, Sensing, Actuation, Basics of Networking, M2M and IoT Technology Fundamentals- Devices and gateways, Data management, Business processes in IoT, Everything as a Service (XaaS), Role of Cloud in IoT, Security aspects in IoT. |
| **Module III** | **Elements of IIoT:** |
| | Hardware Components- Computing (Arduino, Raspberry Pi), Communication, Sensing, Actuation, I/O interfaces. Software Components- Programming API's (using Python/Node.js/Arduino) for Communication Protocols-MQTT, ZigBee, Bluetooth, CoAP, UDP, TCP. |
| **Module IV** | **IIoT Application Development:** |
| | Solution framework for IoT applications- Implementation of Device integration, Data acquisition and integration, Device data storage- Unstructured data storage on cloud/local server, Authentication, authorization of devices. |
| **Module V** | **Smart Applications:** |
| | Online Predictive Modeling, Monitoring and Intelligent Control of Machining/Manufacturing and Logistics/Supply Chain Processes; Smart Energy Management of manufacturing processes and facilities, Agriculture, Healthcare, Home Automation |

| | |
|---|---|
| | **TEXT BOOKS:** |
| 1 | Introduction to Industrial Internet of Things and Industry 4.0, Sudip Misra, Chandana Roy, Anandarup Mukherjee, CRC Press, 2020. |

| | |
|---|---|
| 2 | Smart Manufacturing by Shoukat Ali; Publisher: LAP LAMBERT Academic Publishing(10 August 2016) |
| 3. | Introduction to Internet of Things: A practical Approach", Dr. SRN Reddy, Rachit Thukral and Manasi Mishra, ETI Labs,2010 |
| 4. | The Internet of Things: Enabling Technologies, Platforms, and Use Cases", Pethuru Raj and Anupama C. Raman, CRC Press, 2012 |
| 5. | Designing the Internet of Things, Adrian McEwen, Wiley, 2015 |
| 6. | A. McEwen and H. Cassimally, Designing the Internet of Things, 1st edition, Wiley, 2013, ISBN-10: 111843062X. |

| | |
|---|---|
| **Programme Name** | **Honors/Minor Smart Manufacturing Semester-VIII** |
| **Course Code** | **SM4002T** |
| **Course Title** | **Design for Additive Manufacturing** |

## Course Outcomes

After completion of course, students would be able:

1. Select appropriate material during design process
2. Identify the need of design for additive manufacturing
3. Identify design constraints and choose a polymer and metal AM process
4. Develop lattice structures using topology optimization
5. Apply design for additive manufacturing guidelines in designing mass customized products

## COURSE CONTENTS

| | |
|---|---|
| **Module I** | **Materials Selection in Design** |
| | The families of Engineering materials, the selection strategy, attribute limits and material indices, the selection procedure, computer-aided selection, shape factors, Microscopic or micro-structural shape factors, limits to shape efficiency, exploring and comparing structural sections, material indices that include shape, co-selecting material and shape, case studies |
| **Module II** | **Introduction to Design for Additive Manufacturing (DFAM):** |
| | Introduction to geometric modelling, Modelling of Synthetic curves like Hermite, Bezier and B-spline, Parametric Representation of freeform surfaces, Design freedom with AM, Need for Design for Additive Manufacturing (DfAM), CAD tools vs. DfAM tools, Requirements of DfAM methods, General Guidelines for DfAM, The Economics of Additive Manufacturing, Design to Minimize Print Time, Design to Minimize Post-processing. |
| **Module III** | **Design Guidelines for Part Consolidation:** |
| | Design for Function, Material Considerations, Number of Fasteners, Knowledge of Conventional DFM/DFA, Assembly Considerations, Moving Parts, Part redesign, Opportunities for part consolidation, challenges with part consolidation. |
| **Module IV** | **Design for Improved Functionality:** |
| | Multi scale design for Additive manufacturing, Mass customization, Biomimetics, Generative design, Design of multi-materials and functionally graded materials. |
| **Module V** | **Design for Minimal Material Usage:** |
| | Topology Optimization, Modelling of Design space, defining design and manufacturing constraints, performing analysis for weight reduction, maximize stiffness, minimize displacement, Post-processing and Interpreting Results, Applications of TO, TO tools, Design of cellular and lattice structures, Design of support structures. |
| **Module VI** | **Computational Tools for Design Analysis:** |
| | Considerations for Analysis of AM Parts, Material Data, Surface Finish, Geometry, Simplifying Geometry, Mesh-Based Versus Parametric Models, Build Process Simulation: Model Slicing, Contour Data Organization, Layer-by-Layer Simulation, Hatching Strategies, Scan Pattern Simulation and Tool Path Generation |
| **Module VII** | **Design for Polymer AM:** |

| | |
|---|---|
| | Anisotropy, Wall Thicknesses, Overhangs, Support Material, Accuracy, Tolerances, Layer Thickness, Resolution, Print Orientation, Warpage, over sintering, Hollowing Parts, Horizontal Bridges, Connections, Fill Style, holes, fillets, ribs, font sizes and small details. |
| **Module VIII** | **Design for Metal AM:** |
| | Powder Morphology, Powder Size Distribution, Material Characteristics, Designing to Minimize Stress concentrations, Residual Stress, Overhangs, shrinkage, warpage and Support Material, Design Guidelines for Wall Thickness, Clearance Between Moving Parts, Vertical Slots, Circular Holes, fillets, channels, vertical Bosses, circular pins, External Screw Threads and part positioning. |
| **Module IX** | **Introduction to DfAM using softwares** |
| | Introduction to additive manufacturing simulation tools of commercial softwares such ANSYS Additive Suite, Digimat AM-eXtreme, and Solidworks, Case studies on DfAM using commercial softwares |


| | |
|---|---|
| | **TEXT BOOKS:** |
| 1 | A Practical Guide to Design for Additive Manufacturing, Diegel, Olaf, Axel Nordin, and Damien Motte, Springer, 2020. |
| 2 | The 3D Printing Handbook: Technologies, Design and Applications, Redwood, Ben, FilemonSchoffer, and Brian Garret, 3D Hubs, 2017. |
| 3. | Design for Advanced Manufacturing: Technologies and Process, Laroux K, Gillespie,McGrawHill, 2017. |
| 4. | Additive Manufacturing Technologies, Gibson, Ian, David W. Rosen, Brent Stucker, andMahyar Khorasani, Springer, 2021. |
| | **RECOMMENDED READING** |
| 1 | Laser-Induced Materials and Processes for Rapid Prototyping, L.Lu, J. Y. H. Fuh and Y.S.Wong, Springer, 2001. |
| 2 | Mathematical Elements for Computer Graphics, David F. Rogers, J. A. Adams, TMH,2008. |
| 3. | Materials Selection in Design, Michel Ashby, 2011 |
| 4. | ANSYS Granta, Edupack Manual |

| | |
|---|---|
| **Programme Name** | **Honors/Minor Smart Manufacturing , SEMESTER - VIII** |
| **Course Code** | **SM4002P** |
| **Course Title** | **Design for Additive Manufacturing Laboratory** |

**COURSE OUTCOMES**

After completion of course, students would be able:

1. Understand process and concepts of AM simulation softwares
2. Use AM simulation softwares for better design of parts
3. Optimize the structural designs
4. Design bio-inspired structures.

**List of Experiments:**

1. Introduction to Additive Simulation Softwares
2. Simulation Additive Manufacturing Process using Software
3. Prediction of residual stresses and warpage in FDM process using AM software
4. Topology Optimization using AM Simulation Software
5. Introduction to generative design using Autodesk Fusion 360
6. Analysis of bio-inspired structures
7. 3D printing of bio-inspired structures