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3D PRINTING **Course Code : 315351**

Programme Name/s : **Automation and Robotics**
Programme Code : **AO**
Semester : **Fifth**
Course Title : **3D PRINTING**
Course Code : **315351**

I. RATIONALE

3D printing is a versatile and rapidly evolving technology essential for modern manufacturing, prototyping, and product development. Acquiring skills in 3D printing principles, technologies, and practical techniques ensures that students are prepared to handle various applications, select appropriate materials, and execute effective post-processing. By developing these skills, students will be well-equipped to meet industry demands, contribute to innovative projects, and solve complex challenges in manufacturing of various components required for industrial automation and robotics designs.

II. INDUSTRY / EMPLOYER EXPECTED OUTCOME

The aim of this course is to help students to attain the following industry/employer expected outcome through various teaching and learning experiences-
Apply the knowledge of 3D printing technology for manufacturing tailor-made objects required for robotics, healthcare, automotive, entertainment, consumer goods, and in similar applications.

III. COURSE LEVEL LEARNING OUTCOMES (COS)

Students will be able to achieve & demonstrate the following COs on completion of course based learning

- CO1 - Compare conventional and additive manufacturing processes.
- CO2 - Differentiate between various additive manufacturing processes.
- CO3 - Apply techniques to obtain and slice 3D models.
- CO4 - Select appropriate materials for 3D printing based on desired properties.
- CO5 - Implement post-processing techniques in 3D printing.

IV. TEACHING-LEARNING & ASSESSMENT SCHEME

Course Code	Course Title	Abbr	Course Category/s	Learning Scheme					Credits	Assessment Scheme											
				Actual Contact Hrs./Week			SLH	NLH		Paper Duration	Theory				Based on LL & TL				Based on SL		Total Marks
															Practical						
				CL	TL	LL					FA-TH	SA-TH	Total		FA-PR		SA-PR		SLA		
											Max	Max	Max	Min	Max	Min	Max	Min	Max	Min	
315351	3D PRINTING	TDP	DSE	4	-	2	-	6	2	3	30	70	100	40	25	10	25#	10	-	-	150

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Total IKS Hrs for Sem. : Hrs
Abbreviations: CL- ClassRoom Learning , TL- Tutorial Learning, LL-Laboratory Learning, SLH-Self Learning Hours, NLH-Notional Learning Hours, FA - Formative Assessment, SA -Summative assessment, IKS - Indian Knowledge System, SLA - Self Learning Assessment
Legends: @ Internal Assessment, # External Assessment, *# On Line Examination , @$ Internal Online Examination
Note :

1. FA-TH represents average of two class tests of 30 marks each conducted during the semester.
2. If candidate is not securing minimum passing marks in FA-PR of any course then the candidate shall be declared as "Detained" in that semester.
3. If candidate is not securing minimum passing marks in SLA of any course then the candidate shall be declared as fail and will have to repeat and resubmit SLA work.
4. Notional Learning hours for the semester are (CL+LL+TL+SL)hrs.* 10 Weeks
5. 1 credit is equivalent to 30 Notional hrs.
6. * Self learning hours shall not be reflected in the Time Table.
7. * Self learning includes micro project / assignment / other activities.

V. THEORY LEARNING OUTCOMES AND ALIGNED COURSE CONTENT

Sr.No	Theory Learning Outcomes (TLO's)aligned to CO's.	Learning content mapped with Theory Learning Outcomes (TLO's) and CO's.	Suggested Learning Pedagogies.
1	TLO 1.1 Explain the principle of 3D printing. TLO 1.2 Differentiate between conventional manufacturing and additive manufacturing processes. TLO 1.3 Describe the advantages, disadvantages, and industrial applications of 3D printing.	**Unit - I Basics of 3D Printing** 1.1 Basic principle of 3D printing, steps in 3D printing process 1.2 Conventional v/s Additive manufacturing processes 1.3 3D printer components and its calibration 1.4 Advantages and disadvantages of the 3D printing process 1.5 Industrial applications of 3D printing	Lecture Using Chalk-Board Model Demonstration Presentations Video Demonstrations
2	TLO 2.1 Describe various additive manufacturing processes. TLO 2.2 Select appropriate process parameters for various additive manufacturing techniques. TLO 2.3 Explain the governing bonding mechanisms in different 3D printing technologies.	**Unit - II Additive Manufacturing Techniques** 2.1 Classification of additive manufacturing processes 2.2 Stereo- lithography, laminated object manufacturing, fused deposition modeling, selective laser sintering, selective laser melting, binder jet technology 2.3 Process selection for various applications 2.4 Governing bonding mechanism in 3D printing	Lecture Using Chalk-Board Presentations Video Demonstrations Site/Industry Visit

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Sr.No	Theory Learning Outcomes (TLO's)aligned to CO's.	Learning content mapped with Theory Learning Outcomes (TLO's) and CO's.	Suggested Learning Pedagogies.
3	TLO 3.1 Explain different methods to obtain 3D models. TLO 3.2 Explain various CAD data formats. TLO 3.3 State data translation, data loss & STL format. TLO 3.4 Describe the given method to implement communication between software and 3D printer.	**Unit - III Model Preparation and Data Transfer** 3.1 Different methods to obtain 3D models 3.2 Data exchange formats 3.3 Common slicing softwares 3.4 Common basic slicer settings (layer height, fill density, supports, platform adhesion – skirt, brim, raft, shell thickness) 3.5 Data translation, data loss 3.6 Transferring data from software to printer through: USB, SD card, dedicated controller, Wi-Fi, cloud based	Lecture Using Chalk-Board Presentations Demonstration
4	TLO 4.1 Describe the criteria for selecting materials in 3D printing. TLO 4.2 Explain the properties of polymers, metals, non-metals, and ceramics. TLO 4.3 Explain the features of support materials in 3D printing. TLO 4.4 State the need and applications of hybrid materials used in 3D printing.	**Unit - IV Materials used for 3D Printing** 4.1 Material selection criteria 4.2 Polymers, metals, non-metals, ceramics 4.3 Various forms of raw material- liquid, solid, wire, powder, powder preparation and their desired properties 4.4 Support materials used in 3D printing: Properties & applications 4.5 Hybrid materials : Carbon fiber reinforced filaments, metal-polymer composites, wood-infused filaments, conductive filaments, magnetic filaments	Lecture Using Chalk-Board Collaborative learning Presentations Video Demonstrations
5	TLO 5.1 Explain post-processing techniques used in 3D printing. TLO 5.2 Identify various tools involved for inspection and testing. TLO 5.3 Explain the defects and their causes in 3D printed objects. TLO 5.4 Explain troubleshooting methods in 3D printing.	**Unit - V Post-processing Techniques in 3D Printing** 5.1 Post-processing techniques, need of post-processing, steps in post processing 5.2 Post-processing techniques: Support material removal, surface texture improvements, accuracy improvements, aesthetic improvements 5.3 Inspection and testing of 3D printed objects 5.4 Defects and their causes in 3D printed objects 5.5 Common faults and troubleshooting 3D printer	Lecture Using Chalk-Board Video Demonstrations Model Demonstration

VI. LABORATORY LEARNING OUTCOME AND ALIGNED PRACTICAL / TUTORIAL EXPERIENCES.

Practical / Tutorial / Laboratory Learning Outcome (LLO)	Sr No	Laboratory Experiment / Practical Titles / Tutorial Titles	Number of hrs.	Relevant COs
LLO 1.1 Calibrate the 3D printer bed level for optimal first layer adhesion and print quality. LLO 1.2 Verify temperature settings and filament flow rate to maintain consistent extrusion.	1	*Calibration of 3D printer-bed level, temperature calibration, filament flow rate calibration	2	CO1

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Practical / Tutorial / Laboratory Learning Outcome (LLO)	Sr No	Laboratory Experiment / Practical Titles / Tutorial Titles	Number of hrs.	Relevant COs
LLO 2.1 Simulate the stereolithography process using a virtual lab.	2	Simulation of Stereolithography process	2	CO2
LLO 3.1 Describe the various steps involved in 3D scanning. LLO 3.2 Use 3D scanner to generate 3D model.	3	Generation of 3D model using 3D scanning technology	2	CO3
LLO 4.1 Create a 3D model using CAD software. LLO 4.2 Save and export the 3D model in various data exchange formats.	4	*3D model creation and export using various data exchange formats	2	CO3
LLO 5.1 Use slicing software to set the bed and nozzle temperatures. LLO 5.2 Use slicing software to select printing speed, material, and layer height.	5	*Setting up the bed temperature, nozzle temperature, printing speed, material selection, layer height in slicing software	2	CO3
LLO 6.1 Use slicing software to adjust infill density, pattern, and object orientation. LLO 6.2 Use slicing software to select support material, wall thickness, and convert .stl to .gcode.	6	Setting up infill density, infill pattern, orientation of object, support material, wall thickness and converting .stl file to .gcode file in slicing software	2	CO3
LLO 7.1 Demonstrate the use of 3D printer to print a model with given infill density.	7	*3D printing at given infill density	2	CO4 CO5
LLO 8.1 Use appropriate tools to remove support material. LLO 8.2 Use appropriate tools to enhance surface texture, and improve accuracy of a printed model.	8	*Support material removal, surface texture enhancement, and accuracy improvement of printed model	2	CO5
LLO 9.1 Demonstrate the use of a 3D printer to print details of functional objects. LLO 9.2 Use appropriate tools to remove support material, enhance surface texture, and improve accuracy of printed objects.	9	*Printing and assembling multiple parts to create a functional object	2	CO3 CO4 CO5
LLO 10.1 Identify the common 3D printing defects. LLO 10.2 Resolve the issue that is causing defects in printing.	10	Troubleshooting common 3D printing issues such as layer shifting, warping, stringing, and under-extrusion.	2	CO5

Note : Out of above suggestive LLOs -

- '*' Marked Practicals (LLOs) Are mandatory.
- Minimum 80% of above list of lab experiment are to be performed.
- Judicial mix of LLOs are to be performed to achieve desired outcomes.

VII. SUGGESTED MICRO PROJECT / ASSIGNMENT/ ACTIVITIES FOR SPECIFIC LEARNING / SKILLS DEVELOPMENT (SELF LEARNING)

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Micro project

- Special Note : This list of suggestive microprojects are optional, as there is no SLA component and faculties may encourage students to perform any one of them.
- Design a joint mechanism for a robotic arm that allows for rotational or pivotal movement using CAD software, ensuring accurate dimensions for smooth movement, and print them using a 3D printer.
- Design a nut and bolt using CAD software, ensuring precise dimensions for a proper fit, and print the design using a 3D printer.
- Design a motor mount to securely hold a motor in place on a robot chassis using CAD software, ensuring accurate dimensions and print them using a 3D printer.
- Design a set of interlocking gears using CAD software, ensuring accurate dimensions for smooth movement, and print them using a 3D printer.

Note :

- Above is just a suggestive list of microprojects and assignments; faculty must prepare their own bank of microprojects, assignments, and activities in a similar way.
- The faculty must allocate judicial mix of tasks, considering the weaknesses and / strengths of the student in acquiring the desired skills.
- If a microproject is assigned, it is expected to be completed as a group activity.
- SLA marks shall be awarded as per the continuous assessment record.
- For courses with no SLA component the list of suggestive microprojects / assignments/ activities are optional, faculty may encourage students to perform these tasks for enhanced learning experiences.
- If the course does not have associated SLA component, above suggestive listings is applicable to Tutorials and maybe considered for FA-PR evaluations.

VIII. LABORATORY EQUIPMENT / INSTRUMENTS / TOOLS / SOFTWARE REQUIRED

Sr.No	Equipment Name with Broad Specifications	Relevant LLO Number
1	3D Printer: Build volume- 250 x 250 x 250 mm, Layer resolution- 0.08-0.2 mm, Dimensional tolerance- ± 0.1mm, Print speed- 40-120 mm/sec, Extruder temperature- 280° C, Bed temperature- 100° C, Nozzle size- 0.4 mm, Power requirements- 230V, 50Hz, Supported file formats- .gcode.	1,7,10
2	High End Computers: Processor- i5 or above, RAM- 16 GB, SSD- 256 GB, Graphics Card- 4 GB.	2,3,4,5,6,9
3	3D Scanner: Handheld 3D scanner, Accuracy up to 0.1 mm, Resolution up to 0.2 mm, Scan speed up to 30fps, Texture scan, Real-time on-screen 3D model projection and processing, Along with Processing Software.	3
4	Parametric computer aided design software: like AutoDesk Inventor, FreeCAD, SolidWorks, AutoDesk Fusion 360, Creo, TinkerCAD etc.	3,4
5	Slicing software: like UltiMaker Cura, Simplify3D, Chitubox, PursaSlicer, Slic3r etc.	5,6,9
6	3D Printing material: Filament diameter- 1.75mm, Materials: ABS/PLA/Flexible/PETG etc.	7,10
7	Post-processing tools: Tool handle, Deburring blades, Electronic digital caliper, Cleaning needles, Art knife set, Long nose pliers, Flush cutters, Wire brush, Nozzle cleaning kit, Tube cutter, Print removal spatula, Needle file, Cutting mat, Glue stick, Wire stripper etc.	8,10

IX. SUGGESTED WEIGHTAGE TO LEARNING EFFORTS & ASSESSMENT PURPOSE (Specification Table)

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Sr.No	Unit	Unit Title	Aligned COs	Learning Hours	R-Level	U-Level	A-Level	Total Marks
1	I	Basics of 3D Printing	CO1	6	2	4	6	12
2	II	Additive Manufacturing Techniques	CO2	10	4	4	8	16
3	III	Model Preparation and Data Transfer	CO3	10	4	4	8	16
4	IV	Materials used for 3D Printing	CO4	6	2	4	6	12
5	V	Post-processing Techniques in 3D Printing	CO5	8	4	4	6	14
Grand Total				**40**	**16**	**20**	**34**	**70**

X. ASSESSMENT METHODOLOGIES/TOOLS

Formative assessment (Assessment for Learning)

- Two offline unit tests of 30 marks and average of two-unit test marks will be consider for out of 30 marks.
- For formative assessment of laboratory learning 25 marks. Each practical will be assessed considering 60% weightage to process, 40% weightage to product.

Summative Assessment (Assessment of Learning)

- End semester assessment of 70 marks.
- End semester summative assessment of 25 marks for laboratory learning.

XI. SUGGESTED COS - POS MATRIX FORM

Course Outcomes (COs)	Programme Outcomes (POs)							Programme Specific Outcomes* (PSOs)		
	PO-1 Basic and Discipline Specific Knowledge	PO-2 Problem Analysis	PO-3 Design/ Development of Solutions	PO-4 Engineering Tools	PO-5 Engineering Practices for Society, Sustainability and Environment	PO-6 Project Management	PO-7 Life Long Learning	PSO-1	PSO-2	PSO-3
CO1	2	1	2	-	2	1	2			
CO2	2	2	3	-	2	1	3			
CO3	2	2	3	3	-	2	3			
CO4	3	2	3	-	3	2	3			
CO5	3	2	3	3	2	2	3			

Legends :- High:03, Medium:02,Low:01, No Mapping: -
*PSOs are to be formulated at institute level

XII. SUGGESTED LEARNING MATERIALS / BOOKS

Sr.No	Author	Title	Publisher with ISBN Number

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Sr.No	Author	Title	Publisher with ISBN Number
1	Lan Gibson, David W. Rosen and Brent Stucker,	Additive Manufacturing Technologies: Rapid Prototyping to Direct Digital Manufacturing	Springer Nature,2015, ISBN: 978-1493921126
2	Andreas Gebhardt	Understanding Additive Manufacturing: Rapid Prototyping, Rapid Tooling, Rapid Manufacturing	Hanser Publications, 2012, ISBN: 978-3446425521
3	Chee Kai Chua and Kah Fai Leong	3D Printing and Rapid Prototyping- Principles and Applications	World Scientific, 2019, ISBN: 978-0000987570
4	Sabrie Soloman	3D Printing and Design	Khanna Book Publishing, 2020, ISBN: 978-9386173768
5	Liza Wallach Kloski, Nick Kloski	Getting Started with 3D Printing: A Hands-on Guide to the Hardware, Software, and Services Behind the New Manufacturing Revolution	Make Community LLC, 2016, ISBN: 978-1680450200

XIII . LEARNING WEBSITES & PORTALS

Sr.No	Link / Portal	Description
1	https://onlinecourses.nptel.ac.in/noc21_me115/preview	Fundamentals of Additive Manufacturing Technologies (SWAYAM - NPTEL)
2	https://3dp-dei.vlabs.ac.in/Introduction.html	3D Printing Virtual Simulation Lab (Vlabs)
3	https://www.autodesk.com/solutions/3d-printing	3D Printing Process
4	https://ultimaker.com/software/ultimaker-cura/	Slicing Software - Cura
5	https://www.autodesk.com/education/edu-software/overview	3D modelling software - Autodesk Fusion 360
6	https://www.freecad.org/	3D modelling software - FreeCAD
7	https://www.simplify3d.com/resources/materials-guide/propert ies-table/	Filament Properties Table
8	https://support.3dverkstan.se/article/23-a-visual-ultimaker-troubleshooting-guide	Visual Ultimaker Troubleshooting Guide

Note :

- Teachers are requested to check the creative common license status/financial implications of the suggested online educational resources before use by the students