Program Name : **Diploma in Automation and Robotics**

Program Code : **AO**

Semester : **Sixth**

Course Title : **3D Printing**

Course Code : **22681**

1. RATIONALE

3D printing is a very popular and cost effective technology widely used in the Industry for prototyping, testing and manufacturing objects on the go. Artistic, well-engineered parts with good finishing can be manufactured through the various 3D printing methodologies available now-a-days. Students learning 3D printing will be able to build various robot/ industrial parts.

2. COMPETENCY

The course is designed to impart knowledge and skills related to 3D printing technologies, selection of material and equipment and develop a product using this technique in an Industry 4.0 environment.

- Use 3D technology to build the robots.

3. COURSE OUTCOMES (COs)

The theory, practical experiences and relevant soft skills associated with this course are to be taught and implemented, so that the student demonstrates the following industry oriented COs associated with the above mentioned competency:

After completion of this course, the students will be able to:

a. Develop CAD models for 3D printing.
b. Import and Export CAD data and generate .stl file.
c. Select a 3D printing process for an application.
d. Select a specific material for the given application.
e. Produce a product using 3D Printing or Additive Manufacturing (AM).

4. TEACHING AND EXAMINATION SCHEME

Teaching Scheme			Credit (L+T+P)	Examination Scheme												
				Theory							Practical					
L	T	P		Paper Hrs.	ESE		PA		Total		ESE		PA		Total	
					Max	Min	Max	Min	Max	Min	Max	Min	Max	Min	Max	Min
3	-	2	5	3	70	28	30*	00	100	40	25@	10	25	10	50	20

(*): Under the theory PA, Out of 30 marks, 10 marks are for micro-project assessment to facilitate integration of COs and the remaining 20 marks is the average of 2 tests to be taken during the semester for the assessment of the UOs required for the attainment of the COs.

Legends: ***L****-Lecture;* ***T*** *– Tutorial/Teacher Guided Theory Practice;* ***P*** *- Practical;* ***C*** *– Credit,* ***ESE*** *- End Semester Examination;* ***PA*** *- Progressive Assessment*

5. COURSE MAP (with sample COs, PrOs, UOs, ADOs and topics)

This course map illustrates an overview of the flow and linkages of the topics at various levels of outcomes (details in subsequent sections) to be attained by the student by the end of the course, in all domains of learning in terms of the industry/employer identified competency depicted at the center of this map..

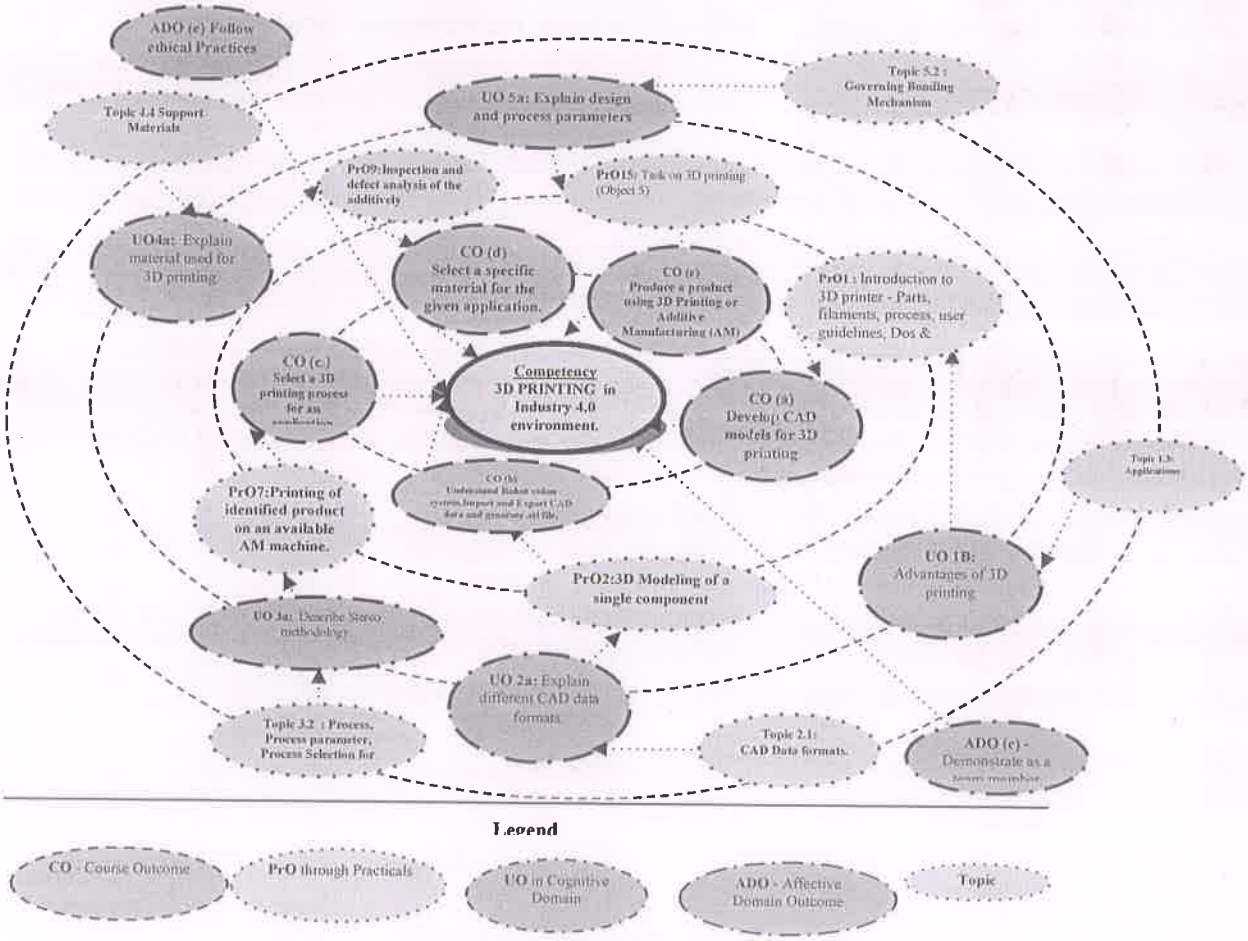

Figure 1 - Course Map

6. SUGGESTED PRACTICALS/ EXERCISES

The practicals in this section are PrOs (i.e. sub-components of the COs) to be developed and assessed in the student for the attainment of the competency.

S. No.	Practical Outcomes (PrOs)	Unit No.	Approx. Hrs. Required
1	Introduction to 3D printer - Parts, filaments, process, user guidelines, Dos & Don'ts	I	2*
2	3D Modeling of a single component.	II	2
3	Assembly of CAD modeled Components	II	2*
4	Exercise on CAD Data Exchange. (How to convert a CAD data or similar data in a format that the other person can understand it. This experiment is more related to the standards that the industry follows for 3D printing files manufacturing. A designer and a manufacturer might be two different people / organizations. They should be able to understand and convert data of one format to another.	II	2
5	Generation of .stl files. - How to generate .stl file - Select parameters like layer thickness, infill, etc.	II	2*
6	Identification of a product for Additive Manufacturing and its AM process plan.	III	2*
7	Printing of identified product on an available AM machine.	III	2*
8	Post processing of additively manufactured product.	III	2
9	Inspection and defect analysis of the additively manufactured product.	IV	2*
10	Comparison of Additively manufactured product with conventional manufactured counterparts.	IV	2
11	Task on 3D printing (Object 1: Example: Whistle)	V	2*
12	Task on 3D printing (Object 2: Example: Gears)	V	2
13	Task on 3D printing (Object 3: Example: Nut & Bolt)	V	2*
14	Task on 3D printing (Object 4: Example: Propeller of Submarine/ ship)	V	2
15	Task on 3D printing (Object 5: Example: Phone stand)	V	2
16	Task on 3D printing (Object 6: Example: Raspberry Pi casing) Other objects: Robot gripper, Ship	V	2
		Total	**32**

Note

i. *A suggestive list of* **PrOs** *is given in the above table. More such PrOs can be added to attain the COs and competency. A judicial mix of minimum 12 or more practical need to be performed, out of which, the practicals marked as '*' are compulsory, so that the student reaches the 'Precision Level' of Dave's 'Psychomotor Domain Taxonomy' as generally required by the industry.*

ii. *The 'Process' and 'Product' related skills associated with each PrO is to be assessed according to a suggested sample given below:*

S. No.	Performance Indicators	Weightage in %
1	Preparation of experimental setup.	20
2	Setting and operation.	20
3	Safety measures.	10
4	Observation and recording.	10
5	Interpretation of result and conclusion.	20
6	Answer to sample questions.	10
7	Submission of report in time.	10
	Total	**100**

The above PrOs also comprise of the following social skills/attitudes which are Affective Domain Outcomes (ADOs) that are best developed through the laboratory/field based experiences:

a. Follow safety practices.
b. Practice good housekeeping.
c. Demonstrate working as a leader/a team member.
d. Maintain tools and equipment.
e. Follow ethical Practices.

The ADOs are not specific to any one PrO, but are embedded in many PrOs. Hence, the acquisition of the ADOs takes place gradually in the student when s/he undertakes a series of practical experiences over a period of time. Moreover, the level of achievement of the ADOs according to Krathwohl's 'Affective Domain Taxonomy' should gradually increase as planned below:

- 'Valuing Level' in 1st year
- 'Organizing Level' in 2nd year
- 'Characterizing Level' in 3rd year.

7. MAJOR EQUIPMENT/ INSTRUMENTS REQUIRED

The major equipment with broad specification mentioned here will usher in uniformity in conduct of experiments, as well as aid to procure equipment by authorities concerned.

Sr. No.	Equipment Name	PrO. S. No.
1	3D printer of print volume approx. 200 mm x 200 mm x 200 mm & Filament - ABS 3kg, PLA 3 kg (different colors)	1, 2, 6, 7, 11-16
2	Basic tools - Screw driver, allen key set, file set, snap off cutter, glue stick, feviquick, paper tape	1, 2, 6, 7, 11-16
3	Computers for software - 3D printer software and interfacing with 3D printer RAM - 4GB Windows OS	1-16
4	Pen drive & SD card reader, USB cable	1-16

8. UNDERPINNING THEORY COMPONENTS

The following topics are to be taught and assessed in order to develop the sample UOs given below for achieving the COs to attain the identified competency. More UOs could be added.

Unit	Unit Outcomes (UOs) (in cognitive domain)	Topics and Sub-topics
1. 3D Printing (Additive Manufacturing)	1a.Introduction and Basic of 3D printing. 1b. Advantages of 3D printing. 1c. Applications of 3D printing.	1.1 Introduction, Process, Classification, Advantages 1.2 Additive v/s Conventional Manufacturing processes. 1.3 Applications of 3D printing.
2. CAD for Additive Manufacturing	2a Explain different CAD data formats. 2b. State Data translation, Data loss & STL format.	2.1 CAD Data formats 2.2 Data translation, Data loss, STL format.
3. Additive Manufacturing Techniques	3a.Describe Stereo methodology. 3b.Explain process selection for various applications. 3c.Explain Additive manufacturing applications.	3.1 Stereo- Lithography, Laminated Object Manufacturing, Fused Deposition Modeling, Selective Laser Sintering, Selective Laser Melting, Binder Jet technology. 3.2 Process parameter, Process Selection for various applications. 3.3 Additive Manufacturing Application Domains: Aerospace, Electronics, Health Care, Defense, Automotive, Construction, Food Processing, Machine Tools
4. Materials used for 3D printing	4a. Explain material used for 3D printing.	4.1 Polymers, Metals, Non-Metals, Ceramics 4.2 Various forms of raw material- Liquid,

	4b. Explain various forms of Raw material. 4c. Describe support materials used in 3D printing.	Solid, Wire, Powder; Powder Preparation and their desired properties, Polymers and their properties. 4.3 Support Materials used in 3D printing.
5. Equipment & Post Processing Techniques	5a. Explain design and process parameters. 5b.Explain common faults and troubleshooting methods. 5c. Explain Post processing techniques. 5d. List methods for inspection and testing.	5.1 Process Equipment- Design and process parameters 5.2 Governing Bonding Mechanism 5.3 Common faults and troubleshooting 5.4 Process Design Post Processing: Requirement and Techniques 5.5 Inspection and testing 5.6 Defects and their causes

Note: To attain the COs and competency, above listed UOs need to be undertaken to achieve the 'Application Level' and above of Bloom's 'Cognitive Domain Taxonomy'

9. SUGGESTED SPECIFICATION TABLE FOR QUESTION PAPER DESIGN

Unit No.	Unit Title	Teaching Hours	Distribution of Theory Marks			
			R Level	U Level	A Level	Total Marks
I	3D Printing (Additive Manufacturing)	04	04	02	02	**8**
II	CAD for Additive Manufacturing	06	04	04	02	**10**
III	Additive Manufacturing Techniques	12	06	06	04	**16**
IV	Materials used for 3D printing	10	04	06	06	**16**
V	Equipment & Post Processing Techniques	16	08	06	06	**20**
	Total	**48**	**26**	**24**	**20**	**70**

10. SUGGESTED STUDENT ACTIVITIES

Other than the classroom and laboratory learning, following are the suggested student-related ***co-curricular*** activities which can be undertaken to accelerate the attainment of the various outcomes in this course: Students should conduct following activities in group and prepare reports of about 5 pages for each activity, also collect/record physical evidences for their (student's) portfolio which will be useful for their placement interviews:

a. List different types of robots and their applications.
b. Visit Industries having robots and tabulate their specification list, understand operational and maintenance practices.
c. Case study on various robot manufacturing companies and gripper manufacturing companies.
d. Download videos of 3D applications, write a report on it and explain.

11. SUGGESTED SPECIAL INSTRUCTIONAL STRATEGIES (if any)

These are sample strategies, which the teacher can use to accelerate the attainment of the various learning outcomes in this course:

a. Massive open online courses (***MOOCs***) may be used to teach various topics/subtopics.
b. ***'L' in item No. 4*** does not mean only the traditional lecture method, but different types of teaching methods and media that are to be employed to develop the outcomes.
c. About ***15-20% of the topics/subtopics*** which are relatively simpler or descriptive in nature is to be given to the students for ***self-directed learning*** and assess the development of the COs through classroom presentations (see implementation guideline for details).
d. With respect to item No.10, teachers need to ensure to create opportunities and provisions for ***co-curricular activities***..
e. Video programs/YouTube may be used to teach various topics and sub topics.
f. Demonstrate students thoroughly before they start doing the practice.
g. Encourage students to refer to different books and websites to have a deeper understanding of the subject.
h. Observe continuously and monitor the performance of students in the Lab
i. Use proper equivalent analogy to explain different concepts.
j. Use Flash/Animations to explain various Robotic actions

12. SUGGESTED MICRO-PROJECTS

Only one micro-project is planned to be undertaken by a student assigned to him/her in the beginning of the semester. In the first four semesters, the micro-project is group-based. However, in the fifth and sixth semesters, it should preferably be ***individually*** undertaken to build up the skill and confidence in every student to become a problem solver so that s/he contributes to the projects of the industry. In special situations where groups have to be formed for micro-projects, the number of students in the group should ***not exceed three.***

The micro-project could be industry application based, internet-based, workshop-based, laboratory-based or field-based. Each micro-project should encompass two or more COs which are in fact, an integration of PrOs, UOs and ADOs. Each student will have to maintain a dated work diary consisting of individual contribution in the project work and give a seminar presentation of it before submission. The total duration of the micro-project should not be less than ***16 (sixteen) student engagement hours*** during the course. The student ought to submit a micro-project by the end of the semester to develop the industry oriented COs.

A suggestive list of micro-projects are given here. Similar micro-projects could be added by the concerned faculty:

a. Design, print, assemble, post process an object of your choice on a 3D printer available in the college Lab.

13. SUGGESTED LEARNING RESOURCES

Sr. No.	Title of Book	Author	Publication
1	"Additive Manufacturing Technologies: Rapid Prototyping to Direct Digital Manufacturing"	Lan Gibson, David W. Rosen and Brent Stucker,	Springer, 2010.

2	"Understanding Additive Manufacturing: Rapid Prototyping, Rapid Tooling, Rapid manufacturing"	Andreas Gebhardt	Hanser Publisher, 2011
3	"3D Printing and Design"	Khanna Editorial	Khanna Publishing House, Delhi
4	"3D Printing and Rapid Prototyping- Principles and Applications"	CK Chua, Kah Fai Leong	World Scientific, 2017
5	"Laser-Assisted Fabrication of Materials"	J.D. Majumdar and I. Manna	Springer Series in Material Science, 2013
6	"Laser-Induced Materials and Processes for Rapid Prototyping"	L. Lu, J. Fuh and Y.S. Wong	Kulwer Academic Press, 2001
7	Numerical Modelling of the Additive Manufacturing (AM) Processes of Titanium Alloy	Zhiqiang Fan And Frank Liou	InTech, 2012.

14. SUGGESTED SOFTWARE / LEARNING WEBSITES:

a. https://www.tinkercad.com/
b. CURA
c. https://youtube.com/c/LEARNWITHNIKHIL1
d. https://en.wikipedia.org/wiki/CAD_data_exchange#:~:text=CAD%20data%20exchange%20is%20a, suppliers%2C%20customers%2C%20and%20subcontractors.)
e. http://www.roboanalyzer.com/virtual-experiments.html.
f. http://www.roboanalyzer.com/mechanalyzer.html
g. http://vlabs.iitkgp.ac.in/mr/
h. https://www.robotshop.com/community/