Program Name : **Diploma in Mechanical Engineering / Plastic Engineering**

Program Code : **ME / PS**

Semester : **Fifth**

Course Title : **Solid Modelling and Additive Manufacturing**

Course Code : **22053**

1. RATIONALE

Mechanical, Plastic, Automobile and allied Industries need to build model based applications which are being developed using "**solid modeling software**". This course deals with concepts of solid modeling to enhance solid modeling skills of diploma students. This course will enable the students to inculcate solid modeling and additive manufacturing concepts and methodology to solve engineering problems.

2. COMPETENCY

The aim of this course is to help the student to attain the following industry identified competency through various teaching learning experiences:

- **Develop 'Solid Models' of given machine components using any parametric CAD software.**

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:

a. Prepare 2D Drawing using sketcher workbench of any parametric CAD software.
b. Generate 3D Solid models from 2D sketch using Part workbench of any parametric CAD software.
c. Prepare assembly of part models using Assembly workbench of any parametric CAD software.
d. Generate orthographic views of 3D solid models/assemblies using drafting workbench of any parametric CAD software.
e. Plot a drawing for given part model/assembly.
f. Print components using 3D Printer/Rapid prototyping machine.

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	
-	-	4	4	--	--	--	--	--	--	--	50#	20	50~	20	100	40	

(*): 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 cognitive domain 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 centre of this map.

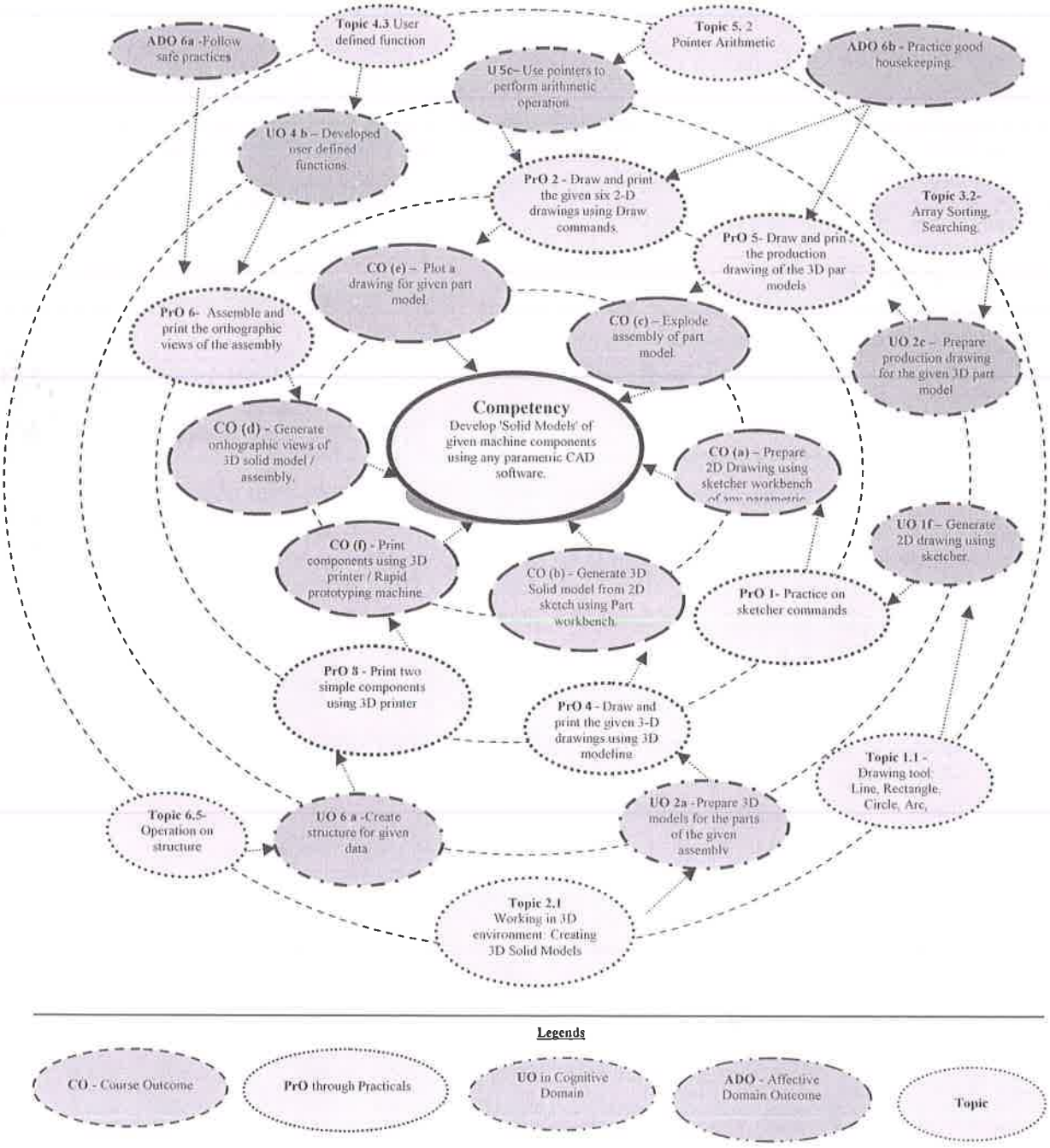

Figure 1 - Course Map

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.	Prepare drawing template consisting of Name plate boundary lines and projection symbol.	I	02
2.	Draw and print two simple 2D geometries using sketcher commands	I, V	02*
3.	Draw and print two complex 2D geometries using sketcher commands	I, V	02
4.	Draw and print the given two simple 3-D drawings using 3D modeling commands	II, V	02*
5.	Draw and print the production drawing of the 3D part models of individual components of Bench vice / Drill Jig / Screw Jack / Tool Post / any assembly consisting of at least five parts.(Problem-I)	II, V	02
6.	Draw and print the production drawing of the 3D part models of individual components of Bench vice / Drill Jig / Screw Jack / Tool Post / any assembly consisting of at least five parts. (Problem -I continued)	II, V	02
7.	Draw and print the production drawing of the 3D part models of individual components of Bench vice / Drill Jig / Screw Jack / Tool Post / any assembly consisting of at least five parts. (Problem -I continued)	II, V	02
8.	Draw and print the production drawing of the 3D part models of individual components of Bench vice / Drill Jig / Screw Jack / Tool Post / any assembly consisting of at least five parts. (Problem -I continued)	II, V	02
9.	Assemble and print the orthographic views of the assembly, bill of materials of Bench vice / Drill Jig / Screw Jack / Tool Post / any assembly consisting of at least five parts. (Problem - I)	III, IV, V	02
10.	Assemble and print the orthographic views of the assembly, bill of materials of Bench vice / Drill Jig / Screw Jack / Tool Post / any assembly consisting of at least five parts. (Problem – I continued)	III, IV, V	02
11.	Draw and print the production drawing of the 3D part models of individual components of Bench vice / Drill Jig / Screw Jack / Tool Post / any assembly consisting of at least five parts.(Problem - II)	II, V	02
12.	Draw and print the production drawing of the 3D part models of individual components of Bench vice / Drill Jig / Screw Jack / Tool Post / any assembly consisting of at least five parts. (Problem - II continued)	II, V	02
13.	Draw and print the production drawing of the 3D part models of individual components of Bench vice / Drill Jig / Screw Jack / Tool Post / any assembly consisting of at least five parts. (Problem - II continued)	II, V	02
14.	Draw and print the production drawing of the 3D part models of individual components of Bench vice / Drill Jig / Screw Jack / Tool Post / any assembly consisting of at least five parts. (Problem - II continued)	II, V	02
15.	Assemble and print the orthographic views of the assembly, bill of materials of Bench vice / Drill Jig / Screw Jack / Tool Post / any	III, IV	02

S. No.	Practical Outcomes (PrOs)	Unit No.	Approx. Hrs. Required
	assembly consisting of at least five parts. (Problem - II)	V	
16.	Assemble and print the orthographic views of the assembly, bill of materials of Bench vice / Drill Jig / Screw Jack / Tool Post / any assembly consisting of at least five parts. (Problem – II continued)	III, IV, V	02
17.	Print simple component using 3D printer / Rapid prototyping machine.	VI	02
18.	Print a complex component using 3D printer / Rapid prototyping machine. (Problem – I)	VI	02
	Total		**36**

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	Use of proper commands	40
2	Completion of drawing with minimum size of model tree	20
3	Generation and printing of drawing views, tables, etc. and their arrangement on different sheet sizes.	20
4	Able to answer oral questions.	10
5	Completion of work 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. Practice energy conservation.
d. Handle solid modeling software carefully.
e. Plan for creation of solid model.
f. Demonstrate working as a leader / a team member.
g. Maintain software tools and equipment.
h. 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

- 'Organising Level' in 2nd year and
- 'Characterising 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.

S. No.	Equipment Name with Broad Specifications	Expt. Sr. No.
1	Hardware: Personal computer, (i3/ i5 or higher), RAM minimum 4 GB, A3 / A4 size printer / plotter. Display-wide Screen preferably.	For all Experiments
2	Operating system: Windows XP/Windows 7/ Windows 8/Windows 10 or higher.	
3	Software: Any parametric solid modeling software.	
4	3D printer / Rapid prototyping Machine.	17, 18

8. UNDERPINNING THEORY COMPONENTS

The following topics/subtopics should be taught and assessed in order to develop UOs for achieving the COs to attain the identified competency.

Unit	Major Learning Outcomes (in cognitive domain)	Topics and Sub-topics
Unit – I Working in 2D environment.	1a. Describe the given sketcher commands. 1b. Demonstrate the given modify commands. 1c. Apply dimensioning and Constraints	1.1 Drawing tool: Line, Rectangle, Circle, Arc, Ellipse, Spline, etc. 1.2 Editing tool: Trim, Extend, Erase, Mirror, etc. 1.3 Modify tool: Chamfer, Fillet, Copy, Move, etc. 1.4 Linear, angular dimensions. 1.5 Dimensioning constraint and Geometrical constraint. 1.6 Drawing template: prepare drawing template consisting of Name plate boundary lines and projection symbol.
Unit– II Development of Solid Models.	2a. Prepare 3D models for the parts of the given assembly using different commands with minimum tree. 2b. Describe intersection of the given Solid. 2c. Prepare production drawing for the given 3D part model / assembly.	2.1 Working in 3D environment: Creating 3D Solid Models of simple machine parts. 2.2 Part tool: Extrude, Hole, Revolve, Rib, Sweep, Swept blend, Pattern, etc. 2.3 Part Editing tool: Trim, Extend, Erase, Mirror, 2.4 Part Modify tool: Chamfer, Round, Copy, Move, Draft, etc. 2.5 Intersect 2 solid components by inserting new body option. Boolean operations: Union, subtract, intersection.
Unit– III Computer aided	3a. Use of assembly tools to prepare assembly using given 3D solid models.	3.1 Assembly Drawing: Preparation of assembly drawing by using assembly command.

Unit	Major Learning Outcomes (in cognitive domain)	Topics and Sub-topics
Assembly	3b. Use of explode command for the given assembly.	3.2 Exploded view: Explode the assembly.
Unit-IV Drafting of 3D assembly	4a. Use drawing module to create orthographic views for the given assembly. 4b. Generate Bill of material for given assembly Drawing.	4.1 Orthographic projections: Generate orthographic projections of the assembly. 4.2 Bill of material: Prepare part list table.
Unit –V Plotting	5a. Use different settings for plotting. 5b. Use printer to plot drawing on A3 or A4 size sheet.	5.1 Printer selection, paper size, orientation. 5.2 Page set up.
Unit-VI Additive Manufacturing	6a. Describe the process of Additive manufacturing. 6b. Study construction and working of 3D printer / Rapid prototyping machine. 6c. Describe materials use for 3D printer / Rapid prototyping machine.	6.1 Additive manufacturing: 3D printing, Rapid prototyping. 6.2 File format: STL (Stereo Lithography). 6.3 3D printer software: part import, orientation, processing and printing.

***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 (INTERNAL) DESIGN

Unit No.	Unit Title	Practical Hours	Distribution of practical Marks			
			R Level	U Level	A Level	Total Marks
I	Working in 2D environment	04	01	01	02	04
II	Development of Solid Models	14	02	01	05	08
III	Assembly Drawing	04	-	01	03	04
IV	Drafting of 3D assembly	04	-	02	02	04
V	Plotting	02	-	01	01	02
VI	Additive Manufacturing	04	-	01	02	03
Total		**32**	**03**	**07**	**15**	**25**

***Legends:** R=Remember, U=Understand, A=Apply and above (Bloom's Revised taxonomy)*
***Note**: This specification table provides general guidelines to assist student for their learning and to teachers to teach and assess students with respect to attainment of UOs. The actual distribution of marks at different taxonomy levels (of R, U and A) in the question paper may vary from above table.*

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. Prepare journals based on practical performed in laboratory.
b. Give seminar on relevant topic.
c. Library/E-Book survey regarding 'Solid modeling' used in manufacturing industries.
d. Prepare power point presentation or animation for drafting/solid modeling/assembly/exploded view/3D printing.
e. List applications of 3D printing.
f. Visit to institute/industry having 3D printer/Rapid Prototyping machine.

11. SUGGESTED SPECIAL INSTRUCTIONAL STRATEGIES (if any)

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

a. Massive open online courses (***MOOCs***) may be used to teach various topics/sub topics.
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/sub-topics*** which is 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. Guide student(s) in undertaking micro-projects.
f. Correlate subtopics with actual design and additive manufacturing.
g. Use proper equivalent analogy to explain different concepts.
h. Use Flash/Animations to explain 3D printing and Rapid prototyping manufacturing methods.

12. SUGGESTED MICRO-PROJECTS

Only one micro-project is planned to be undertaken by a student that needs to be assigned to him/her in the beginning of the semester. In the first four semesters, the micro-project are group-based. However, in the fifth and sixth semesters, it should be preferably be ***individually*** undertaken to build up the skill and confidence in every student to become 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 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 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. **2D drawing**: Each student will collect one or two drawings from the nearby industry/workshop and prepare a 2D drawing from it.
b. **3D model**: Each student will identify a small assembly from the institute workshop/laboratory. Measure the dimensions of each part and prepare sketches.

Using sketches prepared 3D model of parts and assembly. Plot the assembly and detail drawings. (eg. Bench vice, Machine vice, Tool post, Couplings, Joints, Bearings etc.)

c. **3D printing/RPT**: Each student will visit a nearby institute/industry. Collect information regarding troubleshooting of 3D printer/Rapid prototyping machine and prepare a report.

13. SUGGESTED LEARNING RESOURCES

S. No.	Title of Book	Author	Publication
1	CATIA V5R17 for Designers	Sham Tickoo	Softcover, Cadcim Technologies
2	Pro/Engineer Wildfire for Designers	Sham Tickoo	Softcover, Cadcim Technologies
3	Solid Works For Designers Release 2006	Sham Tickoo	Softcover, Cadcim Technologies
4	Autodesk Inventor for Designers: Release 10	Sham Tickoo	Softcover, Cadcim Technologies
5	NX 4 for Designers	Sham Tickoo, Deepak Maini	Softcover, Cadcim Technologies
6	Solid Edge V19 for Designers	Sham Tickoo, Deepak Maini	Softcover, Cadcim Technologies
7			

14. SOFTWARE/LEARNING WEBSITES

a. http://www.solidworks.in/sw/products/3d-cad/3d-solid-modeling.htm
b. http://web.iitd.ac.in/~hegde/cad/lecture/L30_solidmod_basics.pdf
c. https://en.wikipedia.org/wiki/Solid_modeling
d. http://npkauto.com/solid-modeling/
e. https://www.youtube.com/watch?v=vjX4PDJcFOI
f. https://www.youtube.com/watch?v=5BDHS4FN2-
g. https://www.youtube.com/watch?v=JjKs-lePlPY