GUJARAT TECHNOLOGICAL UNIVERSITY

Competency-focused Outcome-based Green Curriculum-2021 (COGC-2021)

Diploma Engineering Syllabus (Semester VII)

Subject Code : 4372305

Subject Name : Recycling of Plastics

Diploma Programme in which this course is offered	Semester in which offered
Plastics Engineering (Sandwich Pattern)	Seventh

1. RATIONALE

Plastics are being used in practically all areas of consumer products, including construction, transportation, packaging, automobile and agriculture. In recent world more concern is on the possible damaging impact of plastics on the environment. A Plastic Diploma engineer has to identify all possible sources of plastic waste generation and do recycling of it with or without energy recovery within government norms. This competency requires the knowledge of various plastic recycling techniques. Hence the course has been designed to develop this competency and its associated cognitive, practical and affective domain learning outcomes.

2. COMPETENCY

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

- **Identify sources of plastic waste and select suitable recycling method of it.**

3. COURSE OUTCOMES (COs)

The practical exercises, the underpinning knowledge and the relevant soft skills associated with this competency are to be developed in the student to display the following COs:

1. Select waste disposal method.
2. Select proper separation method.
3. Identify primary and secondary recycling methods.
4. Analyze various tertiary and quaternary recycling methods.
5. Understand recycling methods of various plastics.

4. TEACHING AND EXAMINATION SCHEME

Teaching Scheme (In Hours)			Total Credits (L+T/2+P/2)	Examination Scheme				
				Theory Marks		Practical Marks		Total Marks
L	T	P	C	CA	ESE	CA	ESE	
3	0	2	5	30*	70	25	25	150

(*): Out of 30 marks under the theory CA, 10 marks are for assessment of the micro-project to facilitate integration of COs and the remaining 20 marks is the average of 2 tests to be taken during the semester for the assessing the attainment 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, **CA** - Continuous Assessment; **ESE** - End Semester Examination.*

5. SUGGESTED PRACTICAL EXERCISES

The following practical outcomes (PrOs) are the sub-components of the COs. *Some of the **PrOs** marked '*' are compulsory, as they are crucial for that particular CO at the 'Precision Level' of Dave's Taxonomy related to 'Psychomotor Domain'.*

Sr. No.	Practical Outcomes (PrOs)	Unit No.	Approx. Hrs. required
1	To study various sources of plastic waste.	I	02
2	To study waste disposal methods.	I	02
3	To perform plastic waste size reduction by mechanicalmethod.	II	02
4	To carry out separation of plastics using float-sinkmethod.	II	02
5	To study various separation methods of paper/plasticmixtures.	II	02
6	To perform primary recycling of plastic using granulators.	III	02
7	To study recycling by chemical modification of plasticwaste.	III	02
8	To study secondary recycling by co-extrusion and co-injection molding.	III	02
9	To study various pyrolysis reactors.	IV	02
10	To study quaternary recycling methods.	IV	02
11	To carry out depolymerisation of PMMA for recovery ofmonomer.	V	02
12	To study recycling methods of PET	V	02
13	To study recycling methods of PVC.	V	02
14	To study recycling methods of HDPE.	V	02
	Total		**28**

Note

i. *More **Practical Exercises** can be designed and offered by the respective course teacher to develop the industry relevant skills/outcomes to match the COs. The above table is only a suggestive list.*

ii. *The following are some **sample** 'Process' and 'Product' related skills (more may be added/deleted depending on the course) that occur in the above listed **Practical Exercises** of this course required which are embedded in the COs and ultimately the competency.*

S. No.	Sample Performance Indicators for the PrOs	Weightage in %
1	Prepare of experimental setup/Equipment	20
2	Operate the equipment setup or circuit	20
3	Follow safe practices measures	10
4	Record observations correctly	20
5	Interpret the result and conclude	30
Total		**100**

6. MAJOR EQUIPMENT/ INSTRUMENTS REQUIRED

This major equipment with broad specifications for the PrOs is a guide to procure them by the administrators to usher in uniformity of practicals in all institutions across the state.

Sr. No.	Equipment Name with Broad Specifications	Pr. No.
1	Granulators	03
2	Crushers, shredder, hammer mill, disk mill	03
3	Electro dynamic separators, wet pulping separator,	04
4	Sink float separator	05
5	Pyrolysis reactors	09
6	Air circulating incinerators	10
7	Laboratory type small extruder	12,13,14
8	Co-injection Machine	08
9	Co-extrusion Machine	08

7. AFFECTIVE DOMAIN OUTCOMES

The following ***sample*** Affective Domain Outcomes (ADOs) are embedded in many of the above mentioned COs and PrOs. More could be added to fulfil the development of this competency.

a) Work as a leader/a team member.

b) Follow ethical practices.
c) Practice environmental friendly methods and processes to avoid metal waste.

The ADOs are best developed through the laboratory/field-based exercises. Moreover, the level of achievement of the ADOs according to Krathwohl's 'Affective Domain Taxonomy' should gradually increase as planned below:

i. 'Valuing Level' in 1st year
ii. 'Organization Level' in 2nd year.
iii. 'Characterization Level' in 3rd year

8. UNDERPINNING THEORY

Only the major Underpinning Theory is formulated as higher level UOs of *Revised Bloom's taxonomy* in order development of the COs and competency is not missed out by the students and teachers. If required, more such higher level UOs could be included by the course teacher to focus on attainment of COs and competency.

Unit	*Unit Outcomes (UOs)* (4 to 6 UOs at Application and above level)	*Topics and Sub-topics*
UNIT – I Sources of Plastic Waste And Its Management	1.a Identify sources of plastic waste 1.b Select waste disposal method	1.1 Introduction to Plastics Waste 1.2 Definitions of related terms – Waste Plastic, Industrial Plastic Waste, Postconsumer Plastic Waste, Nuisance Plastic, Scrap Plastic, Primary Recycling, Secondary Recycling, Tertiary Recycling And Quaternary Recycling 1.3 Economic and environmental impact of Plastic Waste 1.4 Sources of waste – postconsumer, municipal and industrial waste 1.5 Management of plastic waste - 4 R (reduction, reuse, recycling and recovery) 1.6 Plastic cycle - flow of plastic products and plastic waste 1.7 Waste disposal a. Landfill of municipal solid

Unit	*Unit Outcomes (UOs)* (4 to 6 UOs at Application and above level)	*Topics and Sub-topics*
		waste– open dumping and sanitary landfill b. Plastics in landfill c. Future trends
UNIT- II Separation Methods	2. a Identify various separation methods. 2. b Select proper separation method.	2.1 Size reduction by mechanical methods 2.2 Separation of plastics using physical properties 2.3 Separation using recycling codes 2.4 Separation processes specific to plastics a. Separation of paper/plastic mixtures Application of Heat, Wet Separation Process, Electro Dynamic Separation b. Separation of plastic from plastic-coated fabric c. Separation of mixtures of plastics-Float Sink Method, Using Selective Wetting Characteristics, Solvent Separation
UNIT – III Primary & Secondary Recycling Methods	3.a Identify primary and secondary recycling methods 3.b Analyze various methods 3.c Select suitable method	**Primary Recycling** 3.1 Introduction 3.2 Primary recycling methods a. Granulators b. Cryogenic grinding c. Plunger and screw type stuffer d. In-line recycling **Secondary Recycling** 3.3 Introduction to secondary recycling 3.4 Various technical approaches for secondary recycling 3.5 Secondary recycling by mechanical reworking of plastic waste 3.6 Recycling by chemical modification of plastic waste 3.7 Secondary recycling by co-extrusion and co-injection molding

Unit	*Unit Outcomes (UOs)* (4 to 6 UOs at Application and above level)	*Topics and Sub-topics*
		3.8 Use of plastic as a filler
UNIT – IV Tertiary And Quaternary Recycling	4.a Identify tertiary and quaternary recycling methods. 4.b Select proper method	**Tertiary Recycling** 4.1 Pyrolysis a. Introduction to pyrolysis and its advantages b. Introduction to pyrolysis reactors of plastics waste – Union Carbide System, Reactor by Japan Steel Works 4.2 Chemical decomposition of plastic waste a. Hydrolysis b. Glycolysis **Quaternary Recycling** 4.3 Introduction to quaternary recycling 4.4 Constructional features of incinerators 4.5 Incineration of plastic waste and its problems
UNIT – V Recycling Methods Of Specific Plastics	5.a Understand recycling methods of various plastics.	5.1 Describe recycling methods of following plastics : a. PVC b. PET c. PMMA d. HDPE e. LDPE f. PS

***Note**: The UOs need to be formulated at the 'Application Level' and above of Revised Bloom's Taxonomy' to accelerate the attainment of the COs and the competency.*

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	Sources of Plastic Waste and its Management	9	4	8	2	14
II	Separation Methods	8	4	8	2	14
III	Primary & Secondary Recycling Methods	9	3	11	0	14
IV	Tertiary And Quaternary Recycling	8	4	10	0	14
V	Recycling Methods of Specific Plastics	8	4	10	0	14
Total		**42**	**19**	**47**	**4**	**70**

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

1. Students will read various papers on internet regarding various recycling processes.
2. Students will collect different plastic products with recycling codes.
3. Students will prepare identification chart with recycling codes.
4. Students will prepare flow chart of plastic cycle.
5. Students will visit nearby industries and collect information about recycling process.

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) Guide student(s) in undertaking micro-projects.
c) ***'L' in section No. 4*** means different types of teaching methods that are to be employed by teachers to develop the outcomes.
d) About ***20% of the topics/sub-topics*** which are relatively simpler or descriptive in nature is to be given to the students for ***self-learning***, but to be assessed using different assessment methods.
e) With respect to ***section No.11***, teachers need to ensure to create opportunities and provisions for ***co-curricular activities***.
f) Guide students on how to address issues on environment and sustainability.
g) Visit to nearby industries/workshops
h) Video/animation films on collection of materials, sorting and size reduction of plastic waste, various recycling process.

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 is given here. This has to match the competency and the COs. Similar micro-projects could be added by the concerned course teacher:

a) Prepare a chart for different recycle plastics
b) Create a paper recycling station to make new school supplies.
c) Construct benches from eco-bricks made of recycled plastic for outdoor seating.
d) Host a community art project using recycled materials.
e) Build a greenhouse using collected plastic bottles for the school garden.
f) Arrange clean-up events to collect plastic and paper waste, promoting environmental awareness and community involvement

g) Prepare report on Technical Process Flow Chart for Hard Plastic Waste Recycling
h) Prepare presentation on workshops for crafting with recycled plastic and paper.
i) Organize a fashion show featuring outfits made from recycled materials.
j) Collect products made up of co-extrusion/co-injection moulding process.
k) Make model for Recycle, reduce, and recover of waste plastics.
l) Prepare report on various pyrolysis recycling of plastic processes.

13. SUGGESTED LEARNING RESOURCES

Sr. No.	Title of Book	Author	Publication with place, year and ISBN
1.	Plastic Waste	Jacob Leidner	Publication: New York : M. Dekker Publication Year: 1981 ISBN 13 : 9780824713812
2.	Feedstock Recycling of Plastic Waste	Jose Aguado & David Serrano	Publication: Royal Society of Chemistry Publication Year: 1999 ISBN 13 : 9780854045310
3.	Mixed Plastic Recycling Technology	Bruce Hegberg, Gary Brenniman W.H. Hallenback	Publication: New York : M. Dekker Publication Year: 1992 ISBN 13 : 9780815518389
4.	Plastics Fabrication and Recycling	Manas Chanda, Salil K. Roy, Donald E. Hudgin	Publication: CRC Press LLC Publication Year: 2008 ISBN 13 : 9781420080629
5.	Recycling of Plastic Materials	La Mantia	Publication: ChemTec Publishing Publication Year: 1993 ISBN 13 : 9781895198034
6.	Modern Plastics Handbook	Harper	Publication: McGraw-Hill Professional Publication Year: 2000 ISBN 13 : 9780070267145
7.	Plastics waste - feedstock recycling chemical recycling and incineration	Tukker	Publication: New York : M. Dekker Publication Year: 1981 ISBN 13 : 9781859573310
8.	Recycling of PVC and Mixed Plastics Wastes	La Mantia, F.P. (ed)	Publication: ChemTec Publishing Publication Year: 1981 ISBN 13 : 9781895198119
9.	Recycling of Handbook	Lund, Herbert F.	Publication: McGraw-Hill Education Publication Year: 1993 ISBN 13 : 9780070391567

14. SOFTWARE/LEARNING WEBSITES

1. http://www.g.eng.cam.ac.uk/impee/topics/RecyclePlastics/files/Recycling%20Plastic%20v3%20PDF.pdf
2. https://enterclimate.com/blog/methods-of-plastic-waste-management/
3. http://plasticisrubbish.com/2013/03/20/recycling-plastic-2
4. https://www.icpe.in/Plastics%20in%20Food%20Packaging/pdf/14-Final.pmd.pdf
5. https://web.anl.gov/PCS/acsfuel/preprint%20archive/Files/Volumes/Vol42-4.pdf
6. https://en.wikipedia.org/wiki/Plastic_recycling
7. https://www.ecomena.org/recycling-pvc/
8. https://www.inciner8.com/blog/waste-management/the-incinerators-guide-to-plastics
9. https://www.youtube.com/watch?v=tbpjX7GLzMc
10. https://www.ncbi.nlm.nih.gov/books/NBK233614/
11. https://pubs.acs.org/doi/10.1021/acssuschemeng.1c05013
12. https://ebooks.inflibnet.ac.in/esp11/chapter/recycling/

15. PO-COMPETENCY-CO MAPPING

Semester VII	Recycling of Plastic (Course Code: 4372305)									
	POs and PSOs									
Competency & Course Outcomes	PO 1 Basic & Discipline specific knowledge	PO 2 Problem Analysis	PO 3 Design/ development of solutions	PO 4 Engineering Tools, Experimentation &Testing	PO 5 Engineering practices for society, sustainability & environment	PO 6 Project Management	PO 7 Life-long learning	PSO 1 An ability to apply principles of material selection, product & mold/die design and development in plastic engineering.	PSO 2 An ability to conduct safe and environment friendly manufacturing and recycling of plastic products.	PSO 3 (If needed)
Competency 1. Identify sources of plastic waste and select suitable recycling method of it.	3	1	2	1	2	1	2	2	2	-
Course Outcomes 1. Select waste disposal method.	3	1	1	2	2	1	2	3	2	-

2. Select proper separation method.	2	1	1	2	2	1	1	2	2	-
3. Identify primary and secondary recycling methods.	2	1	1	2	2	1	2	3	2	-
4. Analyze various tertiary and quaternary recycling methods.	3	2	2	2	2	1	2	3	2	-
5. Understand recycling methods of various plastics.	2	1	1	2	2	1	2	3	2	-

Legend: '**3**' for high, '**2**' for medium, '**1**' for low or '**-**' for the relevant correlation of each competency, CO, with PO/ PSO

16. COURSE CURRICULUM DEVELOPMENT COMMITTEE

GTU Resource Persons

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