GUJARAT TECHNOLOGICAL UNIVERSITY (GTU)

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

Course Title: Polymer Chemistry
(Course Code: C4322301)

Diploma programme in which this course is offered	Semester in which offered
Plastics Engineering (Sandwich Pattern)	Second

1. RATIONALE

The course deals with structures, properties & fundamentals of polymer preparation by various polymerization techniques. This course will help students to understand micro structure analysis of polymers, its solutions & degradation. Study of this course would make students aware about the concepts of polymer chemistry and morphology for understanding the structure and manufacturing of plastics.

2. COMPETENCY

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

- **Interpret roll of polymer reactions for modification and Manufacturing of industrial polymers in the field of Plastic Engineering**

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 Suitable Polymerization techniques.
2. Interpret glass transition temperature.
3. Describe morphology and its effect on polymer.
4. Compare about polymer degradation mechanism in brief.
5. Identify suitable polymer reaction for polymer modification.
6. Discuss manufacturing process for commodity, engineering and thermoset polymer.

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	-	2	4	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

Following practical outcomes (PrOs) are the sub-components of the Course Outcomes (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'.

S. No.	Practical Outcomes (PrOs)	Unit No.	Approx. Hrs. required
1.	Compare different types of polymerization techniques with respect to its physical parameters.	I	**02**
2.	Prepare Polystyrene by bulk polymerization technique.	I	**02**
3.	To study glass transition temperature and its effect on polymer properties.	II	**02**
4.	Determine T_g of High Density Polyethylene by Dilatometer method.	II	**02**
5.	To study about Molecular weight and its distribution.	III	**02**
6.	To Determine number average molecular weight of Polypropylene by End Group Analysis.	III	**02**
7.	To Determine viscosity average molecular weight of LDPE by viscometry method.	III	**02**
8.	Determination of the Molecular Weight of Polystyrene using Ostwald viscometer.	III	**02**
9.	To study and Compare different types of polymer degradation methods.	IV	**02**
10.	Prepare MMA monomer from depolymerization of PMMA.	IV	**02**
11.	Preparation of (vinyl alcohol) from poly(vinyl acetate) using polymer modification method in laboratory.	IV	**02**
12.	Prepare polymer solution of PVC.	IV	**02**
13.	Prepare Polystyrene by Emulsion polymerization technique.	VI	**02**
14.	Prepare PolyMethylMethacrylate by suspension polymerization method.	VI	**02**
15.	Manufacture Polycaprolactum by Interfacial condensation polymerization technique.	VI	**02**
16.	Preparation of 6-10 Nylon Poly (hexamethylene sebacamide) by Interfacial polymerization.	VI	**02**
17.	Preparation of Polyester from ethylene glycol and maleic anhydride by Interfacial polymerization.	VI	**02**
18.	Prepare Phenol Formaldehyde by Polycondensation process.	VI	**02**
	Total (ANY 10 PRACTICALS)		**36**

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. Care must be taken in assigning and assessing study report as it is a first year study report. Study report, data collection and analysis report must be assigned in a group. Teacher has to discuss about type of data (which and why) before group start their market survey.

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	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

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

S. No.	Equipment Name with Broad Specifications	PrO. No.
1.	Dilatometer	4
2.	Ostwald viscometer with fittings	8
3.	Round bottom flask 500 ml with reflux condenser	10 to 18
4.	500ml three-necked flask	10 to 18
5.	Buchner funnel with filtration flask	10 to 18
6.	Three-necked 500 ml flask	10 to 18
7.	reflux condenser	10 to 18
8.	dropping funnel	10 to 18
9.	Test tube (18 x 150 mm) Glass	10 to 18
10.	Stirring rods as per requirement	10 to 18
11.	Beaker (50 mL, 250 mL 500 mL 1000 mL) Glass	10 to 18
12.	Solvents and Chemicals as per requirement	10 to 18
13.	Safety equipment (gloves, goggles etc) as per requirement	10 to 18
14.	Ring stand and ring with wire gauze	10 to 18
15.	Thermometer as per requirement	10 to 18
16.	Capillary tube as per requirement	10 to 18
17.	Hot water-bath	10 to 18
18.	Drying oven	10 to 18

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 course competency.

a) Work as a leader/a team member.
b) Follow ethical practices.
c) Practice environmental friendly methods for polymer manufacturing and reactions. (Environment related)

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

The major underpinning theory is given below based on the UOs of *Revised Bloom's taxonomy* that are formulated for development of the COs and competency. 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 different levels)	Topics and Sub-topics
Unit – I Polymerization techniques	1a. Understand Polymerization Process 1b. Explain different types of polymerization technique 1c. Compare various polymerization technique 1d. Select polymerization technique suitable for Polymer Manufacturing	1.1 Introduction 1.2 Bulk Polymerization 1.3 Solution Polymerization 1.4 Suspension Polymerization 1.5 Emulsion Polymerization 1.6 Melt Polycondensation 1.7 Solution Polycondensation 1.8 Interfacial Condensation 1.9 Solid and Gas Phase Polymerization
Unit– II **Glass transition temperature**	2a. understand various state of polymer 2b. define glass transition temperature & its effect on polymer. 2c discuss about factors affecting glass transition temperature 2d. relate glass transition temperature of polymer and copolymer	2.1 Introduction 2.2 State & phase A. Glassy state B. Visco-elastic state C. Visco-fluid state D. Solid phase E. Liquid phase 2.3 State of Aggregation 2.4 Orientation of polymer (IBM & EBM) 2.5 Glass transition temperature and associated properties 2.6 Factor Influencing Glass transition temperature 2.7 Glass transition temperature of copolymers 2.8 Glass transition temperature and

		Molecular Weight 2.9 Glass transition temperature and Melting Point 2.10 Glass transition temperature and Plasticizer 2.11 Importance of Glass transition temperature
Unit– III **Structure of polymer**	3a. understand the polydispersity 3b. describe Molecular weight distribution 3c. Explain different microstructure of polymers 3d compare various polymer structure 3e Explain crystallinity . 3f. Distinguish between crystallization and crystallizability	3.1 Introduction 3.2 Polymer morphology 3.3 Dispersity A. Mono Dispersity B. Poly Dispersity 3.4 Molecular weight and its distribution A. Average weight concept B. Types of Molecular weight C. Degree of polymerization A. Significance of Molecular weight 3.5 Microstructure based on A. Chemical structure B. Geometric structure 3.6 Degree of crystallinity 3.7 Crystalline and amorphous structure of polymer 3.8 Polymer crystallization and crystallisability 3.9 Factors affecting crystallisability 3.10 Effect of crystallinity on polymer properties
Unit – IV **Polymer degradation**	4a. List the types of **Polymer** degradation 4b. Explain mechanism and solution for degradation. 4c. Comparison between degradation methods 4d . Identify degradation method for polymer .	4.1 Introduction 4.2 Types of degradation A. Chain-end B. Random 4.3 Thermal Degradation 4.4 Mechanical Degradation 4.5 Ultrasonic wave Degradation 4.6 Photo degradation 4.7 Oxidative Degradation 4.8 Hydrolytic Degradation 4.9 Means to Reduce Polymer degradation 4.10 Factor Affecting Polymer degradation
Unit – V **Polymer reactionsand polymer solutions**	5a. Explain different types of reactions and its applications 5b. importance of polymer reactions 5c. explain polymer dissolution process and its importance 5d. discuss about effect of MW on solubility	5.1 Introduction 5.2 Hydrolysis 5.3 Acidolysis 5.4 Aminolysis 5.5 Hydrogenation 5.6 Addition reactions 5.7 Substitution reactions 5.8 Cross-linked reactions 5.9 Polymer dissolution A. dissolution process B. effect of MW on solubility

Unit – VI **Manufacturing of different Industrial polymers**	6a. Explain the methods of manufacturing commodity polymers. 6b. Explain the methods of manufacturing engineering polymers 6c. Explain the methods of manufacturing thermoset polymers 6d. Manufacture polymer in laboratory synthetization	6.1 Introduction 6.2 Manufacturing process of following Industrial polymers A. Low density polyethylene (LDPE) B. High density polyethylene (HDPE) C. Poly Propylene (PP) D. Poly Vinyl Chloride (PVC) E. Poly Styrene (PS) F. Acrylo Nitryl Butadine Styrene (ABS) G. Poly Amide (Nylon) H. Poly Acetal I. Poly Carbonate J. Poly Methyl Methacrylate (PMMA) K. Poly Urethane (PU) L. Phenol Formaldehyde (PF) M. Urea Formaldehyde (UF) N. Melamine Formaldehyde (MF) O. Epoxy P. Polyester (TS)

***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	Total Marks
I	**Polymerization techniques**	**06**	**06**	**04**	**00**	**10**
II	**Glass transition temperature**	**05**	**06**	**06**	**00**	**12**
III	**Structure of polymer**	**08**	**06**	**03**	**03**	**12**
IV	**Polymer degradation**	**06**	**06**	**04**	**00**	**10**
V	**Polymer reaction and polymer Solutions**	**07**	**05**	**03**	**04**	**12**
VI	**Manufacturing of different Industrial polymers**	**10**	**06**	**04**	**04**	**14**
Total		**42**	**35**	**24**	**11**	**70**

***Legends:** R=Remember, U=Understand, A=Apply and above (Revised Bloom's taxonomy)*
***Note**: This specification table provides general guidelines to assist students for their learning and to teachers to teach and question paper designers/setters to formulate test items/questions to 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 slightly 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 student reports as asked in experiments.
b) Perform experiments as mentioned.
c) Prepare list of Polymer suppliers along with brands, specifications, prices, terms and conditions.

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.10***, 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) Guide students for using raw material data sheet.

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 is 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 duration of the micro project should be about **10-14** ***(ten to fourteen) 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) Polymerization techniques: compare different Polymerization techniques with advantages disadvantages and applications.
b) Glass transition temperature : prepare list of various materials with Glass transition temperature

c) Structure of polymer : prepare a chart of classification of various microstructure of polymers with example

d) Polymer degradation : compare different Polymer degradation and list methods to prevent degradation

e) Polymer reaction and polymer Solutions : prepare list plastic materials that are formed by Polymer modification and compare different Polymerization reaction with advantages, disadvantages and applications

f) Manufacturing of different Industrial polymers : visit Polymerization Manufacturing Plant and prepare report of raw materials used.

13. SUGGESTED LEARNING RESOURCES

Sr. No.	Title of Book	Author	Publication with place, year and ISBN
1	Textbook of Polymer Science	Fred W. Billmeyer	John Wiley & sons, Singapore,2009, 978-0-471-03196-3
2	Polymer Science	Govariker V.R	New Age International Pub, Delhi, 2019, 9788122438130
3	Polymer Science and Technology	Fried J.R	Prentice Hall, Delhi,2014, 9780137039555
4	Polymer Science and Technology	Ghosh Pramamoy	Tata McGrow Hill Education Pvt. Ltd, Delhi, 2010, 9780070707047
5	Polymer Chemistry	Charles E. Carraher Jr.	CRC Press, Delhi, 2017, 9781498737388
6	Plastics Materials	J A Brydson	ISBN: 978-0-7506-4132-6 Publisher: Elsevier Science Published: 22 Nov 1999
7	Polymer Degradation and Stabilization	W. L. Hawkins	ISBN :9783642693762 Publisher: Springer Berlin Heidelberg Published:6 December 2012
8	Thermoplastic Materials: Properties, Manufacturing Methods, and Applications	Christopher C. Ibeh	ISBN 1420093835 Publisher CRC Press Published 25 April 2011

14. SOFTWARE/LEARNING WEBSITES

1. https://www.slideshare.net/Santachem/polymerization-techniques
2. https://nitsri.ac.in/Department/Chemical%20Engineering/M3__Polymer_Technology.pdf

3. https://www.youtube.com/watch?v=5lH_Xt2KUjA video for Glass Transition Temperature
4. https://pslc.ws/index.htm
5. https://omnexus.specialchem.com/polymer-properties/properties/glass-transition-temperature
6. www.sciencedirect.com

15. PO-COMPETENCY-CO MAPPING

Semester I	Basic Polymer Chemistry (Course Code: C4312301)									
	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 **Interpret roll of polymer reactions for modification and Manufacturing of industrial polymers in the field of Plastic Engineering**	3	2	2	3	2	2	3	2	2	-
Course Outcomes Select Suitable Polymerization techniques.	3	1	1	1	1	1	1	1	1	-
Interpret glass transition temperature.	3	2	2	3	1	1	2	1	1	-
Describe morphology and its effect on polymer.	3	2	1	1	1	1	3	1	1	-
Compare about polymer degradation mechanism in detail.	3	2	1	1	1	1	2	1	2	-
Identify suitable polymer reaction for polymer modification.	3	1	1	1	2	1	3	2	2	-

Discuss manufacturing process for commodity, engineering and thermoset polymer	3	1	1	1	1	2	1	1	1	-

Legend: '**3'** for high, '**2**' for medium, **'1'** for low and **'-'** for no correlation of each CO with PO/PSO.

16. COURSE CURRICULUM DEVELOPMENT COMMITTEE

GTU Resource Persons

Sr. No.	Name and Designation	Institute	Contact No.	Email
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