GUJARAT TECHNOLOGICAL UNIVERSITY, AHMEDABAD, GUJARAT

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

Course Title: Joining of Metals
(Course Code: 4332103)

Diploma Programme in which this course is offered	Semester in which offered
Metallurgy Engineering	Third

1. RATIONALE

Diploma Metallurgy Engineers are expected not only to supervise the joining operation carried out in manufacturing workshops, but also take initiatives in selecting suitable process and materials as per the specific needs of different metals and alloys. Since joining of metals is an important manufacturing route to fabricate bulk storage and processing equipments. The subject focuses on knowledge and understanding of various joining process and equipments, the underlying principles and their relative merits and demerits. Basic understanding regarding weldability of different metals and alloys and Welding hazards for the environment, human health, and safety are also duly emphasized. Thus, it is a key course, mastery of which is important for students of metallurgy.

2. COMPETENCY

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

- Identify and join various metals using different welding processes based on the application.

3. COURSE OUTCOMES (COs)

At the end of the study of this course the student will be able to:

- Identify and understand various metal joining techniques, their importance, and weld joint characteristics.
- Discuss the concepts, operating procedures, metallurgical aspects and applications of the soldering and brazing process.
- Describe different fundamental welding and cutting processes, and other advanced welding and cutting processes, in connection to their applications.
- Understand weldability aspects of different materials and apply standards, codes, specification and qualification for a specific welding application.
- Examine quality control, health, environmental issues and safety aspects in welding.

4. TEACHING AND EXAMINATION SCHEME

Teaching Scheme (In Hours)			Total Credits (L+T+P/2)	Examination Scheme				
				Theory Marks		Practical Marks		Total Marks
L	T	P	C	CA	ESE	CA	ESE	
4	0	4	6	30*	70	50	50	200

(*): 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

Sr. No.	Practical Outcomes (PrOs)	Unit No.	Approx. Hrs. Required
1	Understand basic terminology in welding.	I	02
2	Identify the various joint, weld, edge preparation and position of welding.	I	04
3	Perform Soldering and Brazing process for a given material.	II	04
4	Identify the various parts of Gas Welding Set-up and demonstrate & perform Gas Welding Process. (Minimum 2 different Materials)	III	06
5	Identify the various parts of Manual Metal Arc Welding Set-up and demonstrate & perform Manual Metal Welding Process. (Minimum 2 different Materials)	III	06
6	Identify the various parts of Gas Tungsten Arc Welding Set-up and demonstrate & perform Gas Tungsten Arc Welding Process. (Minimum 2 different materials)	III	06
7	Identify the various parts of Gas Metal Arc Welding Set-up and demonstrate & perform Gas Metal Arc Welding Process. (Minimum 2 different materials)	III	06
8	Identify the various parts of Spot Resistance welding Set-up and demonstrate & perform Spot Resistance Welding Process. (Minimum 2 different Materials)	IV	06
9	Identify the various parts of Submerged Arc Welding Process, Electron Beam Welding and Laser Beam Welding machine.	IV	04
10	Demonstrate and perform any one advanced welding process (Activated Flux TIG welding/ Narrow-Gap TIG Welding/ Friction Stir Welding / Flux cored or Metal Cored Arc Welding)	V	04

Sr. No.	Practical Outcomes (PrOs)	Unit No.	Approx. Hrs. Required
11	Demonstrate and perform any one cutting process (Gas Cutting/ Water jet Cutting/ Plasma Cutting/ Laser Cutting)	V	04
12	Identify the welding defects and its causes and remedies.	VI	02
13	Identify the safety gadgets used in welding.	VI	02
	Total Hours		**56**

Notes:

1. 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.
2. 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.

Sr. No.	Sample Performance Indicators for the PrOs.	Weightage in %
1	Identification of the component and Preparation of experimental Set-up	20
2	Operate equipment set-up	10
3	Observation and recording of the data correctly	10
4	Interpretation of the result and conclusion	20
5	Safety precaution and safety gadgets used	20
6	Submission of report within time limit and attendance in the laboratory	20

6. MAJOR EQUIPMENT/ INSTRUMENTS REQUIRED

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

S. No.	Equipment Name with Broad Specifications	PrO. No.
1	**Soldering Station** **Specification:** 850 A SMD Power consumption: 270 Watt Temperature Range: 100 C to 450 C Air Volume: 2264, 24 L/min	**3**
2	**Gas Welding / Cutting Machine** **Specification:** Torch: Both gas welding and Gas cutting Cylinder: Oxygen and Acetylene Regulators: 2 – stage pressure regulators Flashback arrestors: For Oxygen and Acetylene cylinder Flow meter: For Oxygen and Acetylene cylinder Gas hoses: Industrial Grade and length minimum 5 meters.	**2, 4, 11**

3	**Arc Welding Machine** **Specification:** Power Source: Inverter based Main Supply: 3 Phase, 50 Hz Duty Cycle – 60 % Current Range – 20 – 400 Amp OCV – 75 Enclosure Class – IP 21 Insulation – Class H Electrical Fittings: Main Cables, holder, lugs, Earthing arrangement and other required electrical fitting.	**2, 5**
4	**TIG Welding Machine** **Specification:** Power Source: Inverter based Main Supply: 3 Phase, 50 Hz Duty Cycle – 60 % Current Range – 20 – 400 Amp OCV – 75 Enclosure Class – IP 21 Insulation – Class H Cooling arrangement: Air Cooling Assembly with all fittings for torch cooling Ancillaries: Welding torch and its entire assembly Ceramic Nozzle Electrical Fittings: Main Cables, holder, lugs, Earthing arrangement and other required electrical fitting.	**2, 6, 10**
5	**MIG Welding Machine** **Specification:** Power Source: Inverter based Main Supply: 3 Phase, 50 Hz Duty Cycle – 60 % Current Range – 20 – 400 Amp OCV – 75 Enclosure Class – IP 21 Insulation – Class H Ancillaries: Wire feeder with speed 10-20 m/min Welding torch with capability to encompass FCAW, GMAW and MCAW wires Electrical Fittings: Main Cables, holder, lugs, Earthing arrangement and other required electrical fitting.	**2, 7, 10**
6	**Resistance Spot welding set-up** **Specification** Power Source: Thyristor control timer Main Supply: 3 Phase, 50 Hz Duty Cycle: 60 % Power: 15 KVA Maximum short circuit current: 8 to 12 KVA OCV: 80 Nominal Throat clearance: 250 Amps Primary Voltage Supply: 415 Cooling Arrangement: As applicable	**8**

	Ancillaries: Spare copper electrode	
7	Plasma Cutter, 3 Phase, Capacity Up to 15 mm MAX	**11**

7. AFFECTIVE DOMAIN OUTCOMES

The following sample Affective Domain Outcomes (ADOs) are embedded in many of the above-mentioned Cos. More could be added to fulfill the development of this course competency

- Aware about the concept of welding, identifies welding processes and select welding process as per the service requirements.
- Participates in class discussion on welding processes and its application.
- Knows the importance of safety equipment used in welding industry.
- Proposes a plan or ideas to reduce environmental issues arises due to welding activities.
- Work as independently individuals, displays teamwork, displays leadership quality and professional commitment to ethical practice on daily basis.

8. UNDERPINNING THEORY

The major underpinning theory is given below based on the higher level UOs of Revised Bloom's taxonomy that are formulated for development of the COs and competency. If required, more such UOs could be included by the course teacher to focus on attainment of COs and competency.

Unit	Major Learning Outcomes	Topics and Sub-topics
UNIT – I Introduction to Metal Joining Processes	1a Classify metal joining processes and explain their significance in comparison to other manufacturing processes. 1b Describe the different weld joints, type of welds, edge preparation and welding position. 1c Understand basic terminology used for welding.	1.1 Importance and classification of metal joining processes 1.2 Introduction to Welding and classification of welding processes, Importance of welding over other manufacturing processes 1.3 Types of Joints, Types of welds, edge preparation and Welding Position 1.4 Basic Terminology in welding; weld bead dimensions, different zones of weldments, filler metal, heat input, interpass temperature, preheating, post heating.
UNIT – II Soldering and Brazing	2a State basic principle and operation of soldering and brazing process. 2b Describe metallurgical importance of soldering and brazing 2c Compare soldering and brazing process with welding	2.1 Basic principle of soldering, operational steps in soldering process, advantages – disadvantages and applications. 2.2 Basic Principle of Brazing, operational steps in brazing, types of different brazing methods, principles of braze weld, advantages – disadvantages and applications. 2.3 Soldering and brazing alloys 2.4 Comparison of soldering and

		Brazing, comparison of Soldering and Brazing with welding
UNIT – III **Gas Welding and Arc Welding Processes**	3a Define fusion welding processes and classify different Fusion welding processes. 3b Discuss Gas welding process. 3c Define arc welding and identify equipments and power sources used. 3d Explain Physics of arc theory with its effect on welding. 3e State welding electrode classification, storage and electrode polarity with its effect on weld bead. 3f Discuss various arc welding processes. 3g Differentiate Gas welding and Arc Welding	3.1 Classification of Fusion Welding Processes 3.2 Gas Welding; Principle operation, Types of gas welding flames, gas welding techniques, Gas welding equipments, advantages and disadvantages 3.3 Introduction to Arc Welding, equipment and Power sources 3.4 Welding Electrodes, classification of Coating, Care and storage of electrodes 3.5 Arc Initiation, Electrode Polarity and its effect 3.6 Physics of arc and power source characteristics 3.7 Shielded Metal Arc Welding, Gas Tungsten arc Welding, Gas Metal Arc Welding, Sub Merged Arc Welding, Plasma Arc Welding (Principle, Operation, equipment, advantages and disadvantages, application only) 3.8 Thermit welding (Principle, process, advantages and disadvantages, application only)
UNIT – IV **Resistance, Beam and Solid-state Welding Processes**	4a Describe basic principle of resistance welding with its different types based on the application. 4b Explain beam welding processes with its merits, demerits and application. 4c Discuss various pressure/solid-state welding processes.	4.1 Principle of contact resistance, types of resistance welding (Principle, Operation, equipment, advantages and disadvantages, application only) 4.2 Electron beam and Laser Beam welding process (Principle, Operation, advantages and disadvantages, application only) 4.3 Solid state welding processes; Friction welding, cold welding, diffusion welding, explosion welding, forge welding, hot pressure welding, ultrasonic welding etc. process (Principle, Operation, advantages and disadvantages, application only)
UNIT – V Advance Welding processes and Cutting Methods	5a List different advance welding processes explain their procedure based on application. 5b Name various cutting methods and explain based on application.	5.1 Advance welding processes: Activated flux TIG welding, Flux Core Arc Welding, Metal Core Arc welding, Narrow gap welding processes, Underwater welding, Friction Stir welding (Principle, Operation, advantages and disadvantages, application only)

		5.2 Cutting processes such as Gas Cutting, Plasma Cutting, Water Jet Cutting and Laser Cutting (Principle, Operation, advantages and disadvantages, application only)
UNIT – VI Quality control and safety aspects in Metal Joining Processes	6a List various welding defects and state their causes and remedies 6b Understand welding codes and standards 6c List various test and inspection methods to evaluate quality of weld. 6d Describe safety aspects, human health issues, control of hazardous fumes and gases in welding. 6e Define and explain weldability of different metals and alloys. 6f Assess the cost of welding for a given application.	6.1 Welding defects and its prevention 6.2 WPS, PQR, WPQ, codes, standards and specification. 6.3 Testing and inspection of welds during and after welding 6.4 Importance of Human health and Safety aspects in welding. 6.5 Controlling hazardous fumes and gases during welding. 6.6 Weldability, factor affecting weldability 6.7 Weldability of Carbon steel, Stainless steel and Aluminum & its alloy 6.8 Cost effectiveness in welding

9. SUGGESTED SPECIFICATION TABLE FOR QUESTION PAPER DESIGN

Unit	Unit Title	Teaching Hours	Distribution of Theory Marks			
			R Level	U Level	A Level	Total Marks
I	Introduction to Metal Joining Processes	06	6	2	2	10
II	Soldering and Brazing	08	5	3	2	10
III	Gas Welding and Arc Welding Process	12	6	5	4	15
IV	Resistance, Beam and Solid-State Welding Processes	12	6	5	4	15
V	Advance Welding Processes & Cutting Processes	10	5	3	2	10
VI	Quality Control and Safety Aspects in metal Joining Processes	08	5	3	2	10
Total		**56**	**32**	**22**	**16**	**70**

Legends: R = Remember; U = Understand; A = Apply and above levels (Bloom's revised taxonomy)

Notes:

1. This specification table shall be treated as a general guideline for students and Teachers. The actual distribution of marks in the question paper may slightly vary from above Table.

2. Ask the questions from each topic as per marks weightage. Numerical questions are to be asked only if it is specified. Optional questions must be asked from the same topic.

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

1. Make a model/chart for individual Joining processes.
2. Make a chart for hand tools, safety gadgets used in welding and prepare a safety slogan for welding.
3. Prepare safety plan to be used in the event of an accident.
4. Develop a checklist for precaution prior to use of welding or cutting equipment.
5. Perform/compare microstructure of welds prepared using different welding processes for a particular metals and alloys.
6. Industrial Visit of fabrication industries / Manufacturing Industries.
7. Group discussion on environmental issues and control in the fabrication industries.

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)** Encourage students to read codes & standards.

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 he/she 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:

1. Preparation of a Standard Steel Cube.
2. Preparation of Phone stand from scrap metal
3. Make a simple Industrial Pencil Holder
4. Welding Table Torch Holder
5. Creating a welding electrodes storage container
6. Preparation of Different weld joints.
7. Preparation of Models showing welding positions
8. Through hole components soldering
9. SMD component soldering

13. SUGGESTED LEARNING RESOURCES

Sr No.	Title of Book	Author	Publication with place, year and ISBN
1	Welding process & technology	R. S. Parmar	Khanna Publishers, New Delhi, 2003, ISBN: 9788174091260, 8174091262
2	Welding Engineering & technology	R. S. Parmar	Khanna Publishers, New Delhi, 2004, ISBN: 9788174090287, 8174090282
3	Welding technology	O. P. Khanna	Dhanpat Rai Publications Ltd. New Delhi 2010, ISBN: 9383182555, 978-9383182558
4	Metallurgy of welding, Soldering and brazing	J. F. Lancaster	George Allen and Unwin, London, 1970, ISBN: 0046690042, 978-0046690045
5	Modern arc welding techniques	S. V. Nadkarni	Ador Welding Ltd, 2008, ISBN: 8120416767, 978-8120416765
6	ASM Handbook Welding, Brazing and Soldering Volume 6	D. L. Olson, T.A. Siewert, S. Liu, G.R. Edwards	ASM International, 1993 ISBN: 978-0-87170-382-8
7	New developments in Advanced Welding	Nasir Ahmed	Wood head publishing limited, England 2007 ISBN: 9781845690892
8	Advanced Welding Processes – technologies and Process control	John Norrish	Wood head publishing limited, England 2006 ISBN: 978-1-84569-130-1, 978-1-84569-170-7
9	Advances in Welding Technologies for process development	J Vora, V J Badheka	CRC Press, 2019 ISBN 9780367656515

14. SOFTWARE/LEARNING WEBSITES

- http://www.iws.org.in/
- http://www.asme.org
- http://www.aws.org
- http://www.ewf.be
- http://www.astm.org
- https://www.youtube.com/watch?v=-SA4D098u-Q
- https://www.youtube.com/watch?v=XJ1Loh7eF-A
- https://www.youtube.com/watch?v=elmDvqdeMKI
- https://www.youtube.com/watch?v=urjzoypLphk
- https://www.youtube.com/watch?v=uO5pVLOAmD4
- https://www.youtube.com/watch?v=twUAa5LWUvk
- https://www.youtube.com/watch?v=TPSQJXqSwTg
- https://www.youtube.com/watch?v=slAwIfM2kJY
- https://www.youtube.com/watch?v=pZ4-na5JxNw
- https://www.youtube.com/watch?v=svd64WNW8So
- https://www.youtube.com/watch?v=n5bssD7GTlc

15. PO-COMPETENCY-CO MAPPING

Semester II	Joining of Metals (Course Code: 4332103)						
	POs						
Competency & Course Outcomes	PO 1 Basic & Discipline specific knowledge	PO 2 Problem Analysis	PO 3 Design/ develop-ment of solutions	PO 4 Engineering Tools, Experimentation & Testing	PO 5 Engineering practices for society, sustainability & environment	PO 6 Project Manage-ment	PO 7 Life-long learning
Competency	Identify and join various metals using different welding processes based on the application.						
Course Outcomes CO 1) Identify and understand various metal joining techniques, their importance, and weld joint characteristics.	3	-	1	-	-	1	1
CO 2) Explain the concepts, operating procedures, metallurgical aspects and applications of the soldering and brazing process.	3	2	1	1	1	1	1
CO 3) Discuss different fundamental welding and cutting processes, and other advanced welding and cutting processes, in connection to their applications	3	2	1	2	1	1	1
CO 4) Understand weldability aspects of different materials and apply standards,	3	2	3	1	-	1	3

codes, specification and qualification for a specific welding application.							
CO 5) Examine/Survey quality control, health and safety aspects in welding.	2	2	1	1	3	1	2

16. COURSE CURRICULUM DEVELOPMENT COMMITTEE

GTU Resource Persons

S. No.	Name and Designation	Institute	Contact details
1.	Dr. Naishadhkumar P. Patel Lecturer – Metallurgy Engineering	L. E. College (Polytechnic), Morbi	naishad.patel27@gmail.com
2.	Prof. Ravi D. Dave Lecturer- Metallurgy Engineering	Dr. S & SS. Ghandhy College of Engineering and Technology, Surat	rdkdave@gmail.com
3.	Prof. Manish V. Mehta Lecturer – Metallurgy Engineering	Government Polytechnic, Rajkot	manishvmehta019@gmail.com

*****