Department of Metallurgical and Materials Engineering
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i) Details of approved Specialization and dual degree programmes in the following Table:

Table 1: Summary of Specialization and Dual degree leading to Specialization offered by Dept/School/IDRP

Sr. No.	Dept/School/IDRP	Name of Specialization	Eligible Branches	Dual-Degree Possible (Yes/No)	Name of Dual Degree Programme
1	Metallurgical and Materials Engineering	Structural Materials	MT, ME, CI	Yes	Materials Engineering
2	Metallurgical and Materials Engineering	Functional Materials	MT, ME, EE, CH, CIE, BSBE, PH, CY	Yes	Functional Materials
3	Metallurgical and Materials Engineering	Computational Materials Engineering	MT, ME, CS, AI, EE, CH, CI, BSBE, PH, CY	Yes	Computational Materials Engineering

B.Tech Specialization 1: Structural Materials

Table 2: List of Specialization Core and Electives as per Senate approved document

	List of core courses [8 Credits]		List of Elective courses [12 Credits]
1	MTL 4XXX: Failure of Materials and Prevention [3-0-0]	1	MTL 4XXX: Creep and Superplastic Deformation in Materials [3-0-0]
2	MTL7XXX: Plastic Deformation and Microstructure Evolution [3-0-0]	2	MTL 4XXX: Heat-Treatment of Metals and Alloys [3-0-0]
3	MTL7XXX: Imperfections in Solids [1-0-0]	3	MTL 7XXX: Material Aspects in Additive Manufacturing [3-0-0]
4	MTP7XXX: Structural Materials Laboratory [0-0-2]	4	MTL 7XXX: Thermo Mechanical Processing [3-0-0]
		5	MTL 7XXX: Light Metals and Alloys [3-0-0]
		6	MTL 7XXX: Processing of Polymer Matrix Composites [2-0-0]
		7	MTL 4XXX: Fundamentals of Transmission Electron Microscopy [3-0-0]
		8	MEL4XXX: Principle of Biomechanics [3-0-0]
		9	CI4XX0: Introduction to Structural Health Monitoring [3-0-0]
		10	MEP7XX0 Smart Manufacturing [1-0-2]
		11	CHL7XX0: Structure & Property for Polymers [3-0-0]

		12	MTD 7XXX: Project [0-0-6] /[0-0-8]/[0-0-12]

Table 3: Proposed Semester-wise Structure of **20 Graded Credits** and positioning of core courses for Structural Materials Specialization

	Courses	GC		Courses	GC
	V Semester			VI Semester	
	One 400 level 3 credit course may be placed in this semester for overloading		SC	Imperfections in Solids	1
			SC	Failure of Materials and Prevention	3
			Overload this semester 3-4 credits		
				Total	**4**
	VII Semester			VIII Semester	
SC	Plastic Deformation and Microstructure Evolution	3	SC	Structural Materials Laboratory	1
SE	Specialization Elective	3	SE	Specialization Elective	3
SE	Specialization Elective	3	SE	Specialization Elective	3
Overload this semester 4-3 credits			**Overload this semester 3 credits**		
	Total	**9**		Total	**7**

Note: Students will also be required to complete any non-graded credits associated with a minor programme.

Dual Degree in Materials Engineering, Transition through Specialization 1 (Structural Materials)

Table 4: Credit requirements for dual degree

	Specialization Core	**Programme Core Credits**	**Specialization Elective**	**Programme Elective Credits**	**Open Electives Credits**	**M.Tech Project**	**Non-Graded Credits**
Semester VI and VII during Specialization	7	0	6	0	0	0	0
Semester VIII - X	1	2	9	6	3	20	2
Total (As per Dual Degree requirement)	8	2	15	6	3	20	2
	31 (Compulsory + Elective)				**3**	**20**	**2**

Table 5: List of Dual Degree Programme Core (Excluding courses of Preparatory nature)

	List of core courses [Credits]
1	Industry 4.0: Applications in Metallurgical and Materials Engineering [2-0-0] **(MC)**

Note: List of Specialization Core up to VIII Semester will be as per B.Tech. (Specialization) curriculum
List of Specialization Electives up to VIII Semester will be as per B.Tech. (Specialization) curriculum
List of Specialization Electives in IX th Semester will be as per Structural Materials Course Bouquet of M.Tech.Materials Engineering Curriclum
List of Program Electives in IX Semester will be as per M.Tech. Functional Materials and Computational Materials Engineering Course Bouquet

Table 6a: Proposed Semester-wise Structure of **54-56 Graded and 4 Non-Graded Credits** and positioning of core courses for the specialization leading to dual degree **[**B.Tech.+M.Tech.]

	Courses	NC	GC		Courses	NC	GC
	V Semester				VI Semester		
	One 400 level 3 credit course may be placed in this semester for overloading		-	SC	Imperfections in Solids		1
				SC	Failure of Materials and Prevention		3
				Overload this semester 4 credits			
					Total		**4**
	VII Semester				VIII Semester		
SC	Plastic Deformation and Microstructure Evolution		3	SC	Structural Materials Laboratory		1
SE	Specialization Elective		3	SE	Specialization Elective		3
SE	Specialization Elective		3	SE	Specialization Elective		3
Overload this semester 3 credits				**Overload this semester 3 credits**			
	Total		**9**		Total		**7**
	IX Semester				X Semester		
MC	Industry 4.0: Applications in Metallurgical and Materials Engineering		2	MO	Open Elective		3
SE	M.Tech. Specialization Elective		3	MP	M.Tech. Project		15
ME	M.Tech. Program Elective 1		3				
ME	M.Tech. Program Elective 2		3				

MP	M.Tech. Project		5				
	Non-graded PG courses	1	-		Non-graded PG courses	1	-
	Total	**1**	**16**		Total	**1**	**18**

Note:

- The total of semester VI+VII+VIII should be 20 graded credits and IX+X would be graded 34 credits
- Graded credit requirements for M.Tech. is 54, whereas 2 Non-graded requirements.
- Courses out of 11-12 Credits of Specialization done in Semester VI and Semester VII if not part of M.Tech. Programme will be counted towards M.Tech. PE.
- Students will be required to complete all MTech. Core courses except for preparatory courses. Students will be required to take additional credit of Programme Elective against preparatory courses.
- Clearly state courses of M.Tech. core/electives UG students cannot take due to significant overlap with Minor/Specialization core/elective

Course Title	**Imperfections in Solids**	Number	MTL7XXX
Department	Metallurgical and Materials Engineering	L–T–P	1–0–0
Offered for	B.Tech. Specialization, B.Tech.-M.Tech. Dual Degree	Type	Structural Materials Specialization Core (UG)
Pre-requisite			

Objectives

1. To introduce types of defects in materials and their roles in determining material properties

Learning Outcomes

1. To be able to relate how imperfections in materials govern properties and material response

Course Content

Introduction: Structural defects based on dimension, electronic defects, properties influenced by defects (2 lecture)

Point and electronic defects: Intrinsic and extrinsic defects, point defect notations, Brouwer diagram, measurement of point defect concentration (5 lectures)

Extended Defects: misfit dislocations, interfaces, coincident site lattice, tilt and twist boundaries, grain boundary dislocations, vacancy diffusion along GBs, domain boundaries (7 lectures)

Books

1. Cai, W, Nix, W., (2016), *Imperfections in Crystalline Solids*, 1st Ed., Cambridge University Press
2. Hull, D, Bacon, D.J., (2011), *Introduction to Dislocation*, 5th Ed., Butterworth-Heinemann

References:

1. Tilley, R., (2008), *Defects in Solids*, Wiley
2. Sutton, A.P, Balluffi, R.W., (2007), *Interfaces in Crystalline Materials*, Reprint edition, Oxford University Press

Online Course Material

1. Prof. S. Shekhar, Defects in Crystalline Solids (Part-I), NPTEL Course Material, Indian Institute of Technology Kanpur, https://nptel.ac.in/courses/113104081

2. Prof. S. Shekhar, Defects in Crystalline Solids (Part-II), NPTEL Course Material, Indian Institute of Technology Kanpur, https://archive.nptel.ac.in/courses/113/104/113104085/

Course Title	**Failure of Materials and Prevention**	Number	MTL4XXX
Department	Metallurgical and Materials Engineering	L–T–P	3–0–0
Offered for	B.Tech. Specialization	Type	Structural Materials Specialization Core
Pre-requisite			

Objectives

1. To introduce methods for defining and evaluating failure of structural materials and components subjected to steady and time dependent multi-axial (3D) stresses/strains.
2. To introduce materials selection strategies to prevent failure in design.

Learning Outcomes

3. To be able to apply failure theories to predict failure of structural materials and components subjected to various loading conditions.
4. To be able to select materials to prevent failure of components.

Course Content

Introduction: Review of processing-structure-property relation in materials, types of failure *[2 Lectures]*

The Design Process and Materials Data: Design tools and Materials data, Processes of obtaining materials data, Materials databases *[2 lectures]*

Failure Prediction: Failure Theories, Yield surface and normality, Plastic Stress-Strain Relationships, Griffith's crack theory, Strain energy release rate, Failure modes in polymers and ceramics, Fracture toughness of engineering materials, Use of Fracture Mechanics Principles in Design *[8 lectures]*

Failure Detection via NDT: Visual inspection, Dye-penetration technique, surface and subsurface crack detection through eddy current, internal crack detection via ultrasonic technique [4 lectures]

Application of Failure Theories under Cyclic Loading: S-N Diagram, Cumulative Fatigue Damage, Spectrum Loading, Rainflow counting techniques, Local Strain Life Approach, Damage tolerance and fatigue crack growth in design *[6 Lectures]*

Application of Failure Theories under High Temperature: Creep Mechanism Maps, High Temperature Fracture modes, Presentation of Engineering Creep data, Stress-rupture data, Larson-Miller parameter, Design for Creep *[6 lectures]*

Material Selection for Failure Prevention: Selection criteria for materials, Material Property Charts, property limits and material indices, Materials indices which include shape, Applications of Failure theories under combined loading and application of Granta Edupack for Material Selection, Case studies on applications to life analysis and design *[14 lectures]*

Textbooks

1. *Collins, J.A., (1993), Failure of Materials in Mechanical Design, 2nd Edition, Wiley-Interscience Publication*
2. Hertzberg, R.W., (2013), *Deformation and Fracture Mechanics of Engineering Materials,* 5th Edition, Wiley
3. *Ashby, M.F., (2016), Materials Selection in Mechanical Design, 5th Edition, Butterworth-Heinemann*

Reference Books:

1. Courtney, T. H., (2005), *Mechanical Behaviour of Materials*, 2nd Edition, Waveland Press Inc.
2. Jones, D.R.H., and Ashby,M.F., (2011), *Engineering Materials 1: An Introduction to Properties, Application and Design,* 4th Edition, Butterworth-Heinemann

3. Jones, D.R.H., and Ashby,M.F., (2012), *Engineering Materials 2: An Introduction to Microstructure and Processing,* 4th Edition, Butterworth-Heinemann
4. Shigley, J. E., Mischke, C., Nisbett, K., and Richard, B., *(2008), Mechanical Engineering Design,* McGraw Hill Education
5. *William T. Becker; Roch J. Shipley, Failure Analysis and Prevention, Volume 11, ASM Handbook*

Online Course Material

1. Bhattacharya, B., *Materials Selection and Design,* NPTEL Course Material, Department of Mechanical Engineering, Indian Institute of Technology Kanpur, http://nptel.ac.in/courses/112104122/
2. Sen, I., Fracture, Fatigue and Failure of Materials, NPTEL Course Material, Department of Metallurgical and Materials Engineering, Indian Institute of Technology Kharagpur, https://onlinecourses.nptel.ac.in/noc22_mm42/

Course Title	**Creep and Superplastic Deformation in Materials**	Number	MTL4XXX
Department	Metallurgical and Materials Engineering	L–T–P	3–0–0
Offered for	B.Tech. Specialization	Type	Structural Materials Specialization Elective
Pre-requisite			

Objectives

5. To provide the knowledge in deformation response of materials at elevated temperature
6. To study creep as a failure mode in materials
7. To introduce superplasticity phenomenon in materials

Learning Outcomes

1. To understand high temperature deformation of materials and evaluate the constitutive relations
2. To understand the microstructural engineering required for attaining creep resistance in materials
3. To comprehend the mechanistic understanding of superplastic phenomenon

Course Content

Deformation of materials at elevated temperature: stress-strain behavior, effect of strain rate, effect of temperature, constitutive relationship, strain rate sensitivity, grain size and stress exponent, thermally activated deformation *(15 lectures)*

Creep in materials: Phenomenology of creep, the creep curve, microstructural aspects for creep in metals and ceramics, mechanisms of creep, deformation mechanism map, power law break down, cavitation during creep, Stress rupture and Creep testing methodology, Design against creep *(15 lectures)*

Superplasticity in metals and ceramics: introduction to superplasticity, flow stress vs strain rate sensitivity considerations and mechanism of superplasticity, activation energy for superplastic deformation, microstructural aspects in superplasticity, Failure during superplastic deformation, superplastic forming *(12 lectures)*

Text Books

1. Dieter G.E.,(1986), Mechanical Metallurgy, 3rd Edition, McGraw Hill Book Company
2. Nieh, T.G., Wadsworth, J., Sherby, O.D., (1997) Superplasticity in Metals and Ceramics, Cambridge University Press, Cambridge
3. Polreer J.P., (1984) Creep of crystals, Cambridge University Press, Cambridge,

Reference Material:

1. Courtney, T. H., (2005), *Mechanical Behaviour of Materials*, 2nd Edition, Waveland Press Inc.
2. Kashyap, B.P., Arieli, A., Mukherjee, A.K., Microstructural aspects of superplasticity, (1985) J. Mater. Sci., 20: 2661-2686.
3. Langdon, T.G., (1991) Creep: Concise Encyclopaedia of Advanced Ceramic Materials, New York, Pergamon Press

Online Course Material:

1. Gollapudi S., Creep deformation of Materials, NPTEL Course Material, School of Minerals, Metallurgical & Materials Engineering, Indian Institute of Technology Bhubaneshwar, https://nptel.ac.in/courses/113106088

Course Title	**Heat Treatment of Metals and Alloys**	Number	MTL4XXX
Department	Metallurgical and Materials Engineering	L–T–P	3–0–0
Offered for	B.Tech. Specialization	Type	Structural Materials Specialization Elective
Pre-requisite	Physical Metallurgy (MTL2015)		

Objectives

8. To understand the foundation of heat treatment processes affecting the microstructures.
9. To learn different types of furnaces used in heat treatments and heating mechanisms.
10. Heat transfer mechanisms in heat treatment processes and associated microstructures.

Learning Outcomes

1. Concept behind the microstructure under equilibrium and non-equilibrium cooling. To acquaint with TTT and CCT diagrams and associated microstructure under different industrial cooling conditions.
2. Significant roles of microstructural features on mechanical properties of metals and alloys.

Course Content

Heat treatment process variables; Heating and cooling of steels for heat treatment; Formation of austenite, Transformation of austenite to pearlite, bainite and martensite; Characteristics of transformation products; Homogeneity of austenite; Austenite grain size, Determination and importance of austenitic grain size *[08 Lectures]*

T-T-T-and C-C-T diagrams: Factors affecting T-T-T curves; Prediction of T-T-T-and C-C-T diagrams; Heat treatment processes: different types of annealing, spheroidizing, normalzing, hardening, tempering, patenting, austempering, martempering, sub-zero treatment, Application of Thermo-Calc and DICTRA *[11 Lectures]*

Thermo-mechanical treatment of steels: Ausforming, Isoforming, Cryoforming; Heat removal mechanisms; Hardenability of steels; Heat treatment defects, Residual stress upon heat treatment, Industrial heat treatment practices *[06 Lectures]*

Surface heat treatments - Carburizing, Nitriding, Cyniding and Carbonitriding, Flame hardening, Induction hardening, Laser hardening *[04 Lectures]*

Heat treatment of some steels: IF steel, DP steel, TRIP steel, high speed steels, maraging steels, spring steels. *[04 Lectures]*

Age Hardening; Heat treatment of non-ferrous metals and alloys - Aluminium alloys, Magnesium alloys, Copper alloys, Titanium alloys and Nickel alloys. *[07 Lectures]*

Practical considerations in heat treatment: Industrial Heat Treatment Processes, Types of furnaces and furnace atmospheres, Cooling media *[02 Lectures]*

Text Books

4. Rajan TV, Sharma, CP and Sharma, A. (2011), *Heat Treatment: Principles and Techniques*, 2nd edition, Prentice Hall India.
5. Krauss G. (1990), *Steels - Heat Treatment and Processing Principles*, ASM International, Materials Park, Ohio.
6. Bhadeshia,H.K.D.H, Honycombe,R.W.K, (2017), *Steels: Microstructures and Properties*, 4th Edition, Butterworth-Heinemann

Reference Books:

6. Thelning KE (1984), *Steel and its Heat treatment*, 2nd edition, Butterworth, London.
7. ASM, Metals Hand Book: Heat Treating (1990), Vol. 4, 9th Ed., Metals Parks, Ohio.

Title	**Fundamental of Transmission Electron Microscopy**	Number	MTL4XX0
Department	Metallurgical and Materials Engineering	L–T–P [C]	3–0–0 [3]
Offered for	B.Tech. (MT)	Type	Specialization Elective (SE)
Pre-requisite			

Objectives

1. To introduce the fundamentals of Transmission Electron Microscopy (TEM).
2. Introduce computational techniques of TEM image analysis.

Learning Outcomes

The students will be able to:

1. Simulate the electron diffraction and TEM micrographs.
2. Understand digital micrograph scripting for post-processing the electron micrograph.
3.

Contents

Introduction of basics of TEM: Basics of TEM from instrumental and theoretical perspective, Overview of electron matter interaction in TEM, Wave interference in TEM. (*7 lectures*)

Introduction of various imaging method in TEM: Basics of image formation in TEM, Contrast transfer function, High-resolution TEM imaging (HRTEM) (*7 lectures*)

Scanning transmission electron microscopy imaging (STEM), Bright field imaging, Dark field imaging, spectrum imaging (*7 lectures*)

Introduction of electron diffraction in TEM: Reciprocal lattice, Basics theory of electron diffraction formation in TEM, selected area electron diffraction (SAEDP), Convergent beam electron diffraction (CBED), Electron diffraction analysis methods. (*7 lectures*)

Introduction of spectroscopic method in TEM: Basics of electron energy loss spectroscopy (EELS), Basics EELS analysis for material science (*7 lectures*)

Energy dispersive x-ray in TEM, basics of quantitative chemical analysis by EDS. (*5 lecture*s)

TEM alignment: Basics HRTEM alignment, TEM sample preparation methods. (*2 lectures*)

Textbook

1. Kirkland, E. J., *Advanced computing in electron microscopy*, Springer, 2020.
2. Landup, D., *Data visualization in python with pandas and matplotlib*, 2020.
3. Pennycook S.J., Nellist, P.D., Scanning Transmission Electron Microscopy: Imaging and Analysis, Springer, New York, 2011.

Online Course Material

1. nanoHUB.org - Courses: Transmission Electron Microscopy

Reference Books

1. Beazley, D., Jones, B.K., *Python Cookbook: Recipes for Mastering Python 3 (English Edition)*, O’Reilly media, 2013.
2. Williams, D.B., Carter, C.B, *Transmission Electron Microscopy: A Textbook for Materials Science, Springer,* 2016.