NPTEL Syllabus Template

Course Title	Diffusion in Solids
Discipline	Metallurgy, Materials Science and Engineering
Duration of course 4/8/12 weeks (10/20/30 hours @2.5 hrs/week)	12 weeks
Number of times you have taught this course totally and in the last 5 years (2-3 times is preferable, if not more)	5
Is this course syllabus approved by AICTE or by Senate in your/any institute? If yes, please give the course name and institute under which this is approved.	Yes, the course is approved by the Senate of IIT Hyderabad: MS2290 – Diffusion in Solids
The time frame of when you would want to offer the course: (Jan 2024/July 2024)	Jan 2025
Will it map to any course in the AICTE model curriculum? LINK to AICTE Curriculum LINK 1 LINK 2 LINK 3 LINK 4	PCC-MM203 (Module 2 and 3) PCC-MM204 (Module 5)
Will it map onto any of the NPTEL domain? LINK to Domain page: https://nptel.ac.in/noc/Domain/	Metallurgical & Materials Engineering – Minor in Metallurgy

Name of the Instructor(s)	Dr. Mayur Vaidya	
Department	Materials Science and Metallurgical Engineering	
Institute	IIT Hyderabad	
Email ID	vaidyam@msme.iith.ac.in	
Mobile Phone Number	7879916780	
Website of Instructor	https://msme.iith.ac.in/assets/docs/profiles/MV_CV.pdf	

Intended audience	Undergraduate students and First year PG students
Is it a core/elective course?	Core
Is it a UG/PG/PhD level course?	UG (Relevant for PG and PhD as well)
Is this course relevant for GATE exam preparation?	Yes
Which degrees would it apply to? (BE/ME/MS/BSc/MSc/PhD etc)	BE/ME/MS
What are the next set of courses that can be taken by students who complete this?	Interdiffusion in Solids, Phase Transformations
Pre-requisites in terms of educational qualification of participants, or if any other courses should be done before this course can be taken	None
Industry recognition of this course – List of companies/industry that will recognize/value this online course	Tata Steel, JSW, General Electric, Eaton, Kennametal India, TCS Engineering, Hindalco, MIDHANI, Sandvik. In general, all Materials and Manufacturing Industries that engage in materials processing and design, and the government labs like DMRL, ISRO, BARC, IGCAR
Will the final certification exam be– paper/pen type or computer based - both are proctored	Computer Based
Will the course require use of any software such as MATLAB or any programming language, etc. or any other tool? If yes, does it have a Linux based compiler available or if licensed, can we get the educational license for the same?	The course will use Thermo-Calc Student's edition (available for free for students and teachers) for CALPHAD-based calculations of diffusion profiles using DICTRA module. Sci lab (available for free) to generate solutions to diffusion equations
Names of 2 reviewers for the course (can be from other institutes – will be used if we need any additional inputs on the course) – Name, Dept, email id, Institute	Name : Prof. G. Phanikumar Dept. : MME Institute : IIT Madras Email : gphani@iitm.ac.in Name : Prof. Kaustubh Kulkarni Dept. : MSE Institute : IIT Kanpur Email : kkaustub@iitk.ac.in

List of reference materials/books	1. Mehrer, Helmut. *Diffusion in solids: fundamentals, methods, materials, diffusion-controlled processes*. Vol. 155. Springer Science & Business Media, 2007. 2. Paul, Aloke, Tomi Laurila, Vesa Vuorinen, and Sergiy V. Divinski. *Thermodynamics, diffusion and the Kirkendall effect in solids*. Cham: Springer International Publishing, 2014.

FOR GETTING THE INTRODUCTORY COURSE PAGE READY – TO OPEN FOR ENROLLMENTS

1. Introduce the course in about 4-5 lines

This course introduces the fundamental concepts of diffusion in solids to the students of materials science and metallurgical engineering. Diffusion is a key phenomenon controlling several thermally activated processes in materials. The course offers unique blend of in-depth fundamental diffusion concepts applied to several class of materials such as metallic alloys, semiconductors, ionic solids and nanocrystalline systems. The students will learn to solve diffusion equations following a continuum approach as well as gain understanding of atomic mechanisms of diffusion. The course will also include a DICTRA module where students will learn basics of computational tools for diffusion and get a hands on experience on the same. Techniques to measure the diffusion coefficients are also a part of the course.

2. Photograph of instructor(s)

3. About the instructor(s)

Dr. Mayur Vaidya is currently an Assistant Professor at the Department of Materials Science and Metallurgical Engineering, IIT Hyderabad. Dr. Vaidya's PhD, from IIT Madras, was on diffusion behaviour in high entropy alloys and he has since then expanded his research field to understanding diffusion in variety of materials. His pioneering work on tracer diffusion in high entropy alloys formed the basis of his selection for prestigious Young Scientist award by Indian National Science Academy. Dr. Vaidya has 28 research publications in peer-reviewed journals, with over 1700 citations and h-index of 17. Earlier, Dr. Vaidya did his B. Tech and M. Tech at IIT Madras, during which he received Institute Silver Medal for excellent academic performance. At IIT Hyderabad Dr. Vaidya has taught UG core course on Diffusion in Solids, PG core courses on Advanced Thermodynamics of Materials and Advanced Physical Metallurgy, PG electives on Interdiffusion in solids, high entropy materials and phase transformations. He was awarded Research and Teaching Excellence awards – 2023 by IIT Hyderabad. Dr. Vaidya also featured in top 2% scientist list by Stanford University for years 2022 and 2023.

4. An introductory video about the course (2-5 minutes' duration)

Week No	Lecture no	Original Title
Week 1	Lec 0	Introduction
	Lec 1	Diffusion in materials world
	Lec 2	Revisiting relevant mathematical concepts
	Lec 3	Fick's laws of diffusion
	Lec 4	Introduction to Laplace transform
	Lec 5	Tutorial 1
Week 2	Lec 6	Laplace transformation of Fick's second law
	Lec 7	Solutions to Diffusion equations - 1
	Lec 8	Solutions to Diffusion equations - 2
	Lec 9	Solutions to Diffusion equations - 3
	Lec 10	Tutorial 2
Week 3	Lec 11	Demo of Scilab: Plotting the diffusion profile
	Lec 12	Revisiting structure and defects in crystalline solids - 1
	Lec 13	Revisiting structure and defects in crystalline solids - 2
	Lec 14	Random walk and atomic jumps
	Lec 15	Tutorial 3
Week 4	Lec 16	Atomic mechanisms of diffusion
	Lec 17	Correlation factors - 1
	Lec 18	Correlation factors - 2
	Lec 19	Temperature and pressure dependence of diffusion
	Lec 20	Tutorial 4
Week 5	Lec 21	Revisiting G-X curves and phase diagrams
	Lec 22	Basics of Interdiffusion
	Lec 23	Phase formation in interdiffusion zone
	Lec 24	Concentration profiles in interdiffusion zone - 1
	Lec 25	Tutorial 5
Week 6	Lec 26	Concentration profiles in interdiffusion zone - 2
	Lec 27	Boltzmann-Matano Method
	Lec 28	Kirkendall Effect
	Lec 29	Intrinsic diffusion and darkens equations
	Lec 30	Tutorial 6
Week 7	Lec 31	Introduction to CALPHAD
	Lec 32	Introduction to Thermocalc and DICTRA
	Lec 33	Thermodynamic and kinetic databases
	Lec 34	Homogenization, moving boundary problems
	Lec 35	Tutorial 7

Week 8	Lec 36	Radiotracer diffusion
	Lec 37	SIMS and EPMA
	Lec 38	Mechanical spectroscopy & Electrical Methods
	Lec 39	Nuclear methods - 1
	Lec 40	Tutorial 8
Week 9	Lec 41	Nuclear Methods - 2
	Lec 42	Grain boundary structure and fisher model
	Lec 43	Kinetic regime of grain boundary diffusion
	Lec 44	Dislocation pipe diffusion
	Lec 45	Tutorial 9
Week 10	Lec 46	Diffusion in nanocrystalline materials
	Lec 47	Diffusion in Intermetallics
	Lec 48	Diffusion in quasicrystalline alloys
	Lec 49	Diffusion in metallic alloys-1
	Lec 50	Tutorial 10
Week 11	Lec 51	Diffusion in metallic alloys-2
	Lec 52	Diffusion in high entropy alloys
	Lec 53	Diffusion in semiconductors-1
	Lec 54	Diffusion in semiconductors-2
	Lec 55	Tutorial 11
Week 12	Lec 56	Diffusion in glasses-1
	Lec 57	Diffusion in ionic solids-1
	Lec 58	Diffusion in ionic solids-2
	Lec 59	Revision of important concepts
	Lec 60	Tutorial 12

TA Details			
	:	Teaching Assistant 1	Teaching Assistant 2
Name	:	Ms. Bhawna Yadav	Ms. Tamanna Panigrahi
Department	:	MSME	MSME
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Currently pursuing degree	:	PhD	PhD

Novelty of the proposed Course

Although there is one related course (NOC: Diffusion in multicomponent solids) available on NPTEL, the proposed course has several unique topics, which makes it qualify as a separate course. These are listed below:

a) Kinetic simulations: **Lecs 31-34** are dedicated to using Thermocalc and DICTRA and using them to perform basic kinetic simulations. This is not only a unique topic of this course, but the live demonstrations of the software for problem solving will lend an active learning component to the students as they will be able to perform calculations while they listen to the content.
b) Diffusion measurement techniques: **Lecs 36 - 41** – This novel aspect of the course aims to teach students the basis of techniques used to determine the diffusion coefficients. The experience of the instructor in using several of the techniques mentioned will enhance the learning experience of the students.
c) High diffusivity paths: **Lecs 42 - 46**– It will introduce the concept of Grain boundary diffusion, dislocation diffusion and their application to understand the diffusivity in nanocrystalline materials.
d) Diffusion in important class of materials: **Lecs 47-58** – Diffusion plays a very important role not only in metallic systems, but in several other materials such as semiconductors, ionic solids, and glasses. Over a span of two weeks, this course would give students key concepts in understanding diffusion behaviour of these important classes of materials.
e) Use of Scilab: Students will be shown to plot some of the solutions to diffusion equations **(Lecs 11)** using open-source software Scilab. I believe, such hands-on experience will make the learning more active and interesting, and students will be able to grasp the concepts easily.