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)	July 2024
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 24 research publications in peer-reviewed journals, with over 1000 citations and h-index of 14. Earlier, Dr. Vaidya did his B. Tech and M. Tech at IIT Madras, during which he received Institute Silver Medal for excellent academic performance. In his short research career.

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 Teaching Excellence award – 2023 by IIT Hyderabad.

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

Weekly Course Plan			
Weeks		Lecture Names	Assignments
Week 1	:	**Module 1 – Fick’s Laws of Diffusion** Lec 1 - Diffusion in materials world Lec 2 – Fick’s first law of diffusion Lec 3 - Fick’s second law of diffusion Lec 4 - Introduction to Laplace transform Lec 5 - Tutorial 1	Online
Week 2	:	**Module 2 – Solutions to diffusion equations** Lec 6 - Laplace transformation of Fick's second law Lec 7 - Instantaneous source problem Lec 8 - Constant source problem Lec 9 - Demo of Scilab: Plotting the diffusion profiles. Lec 10 - Tutorial-2	Online
Week 3	:	Lec 11 - Solution of diffusion couple Lec 12 - Solution for Homogenization Lec 13 - Vacuum degassing Lec 14 - Demo of Scilab: Plotting the diffusion profile. Lec 15 - Tutorial-3	Online
Week 4	:	**Module 3 – Atomic Mechanisms of Diffusion** Lec 16 - Types of diffusion mechanisms Lec 17 - Relation between jump frequency and the diffusion coefficient Lec 18 - Effect of temperature on diffusion coefficient Lec 19 - Diffusion mechanisms in Intermetallics-1 Lec 20 - Tutorial -4	Online

Week 5	:	Lec 21 - Diffusion Mechanisms in Intermetallics-2 Lec 22 - Random walk of atoms Lec 23 - Einstein-Smoluchowski Relation Lec 24 - Concept of correlation factor Lec 25 - Tutorial -5	Online
Week 6	:	**Module 4 – Interdiffusion** Lec 26 - Basics of interdiffusion Lec 27 - Revision of G-X curves and phase diagrams Lec 28 - Chemical potential as driving force for diffusion. Lec 29 - Phase formation in interdiffusion Lec 30 - Tutorial-6	Online
Week 7	:	Lec 31 - Concentration profiles in interdiffusion Lec 32 - Boltzmann-Matano Method Lec 33 - Kirkendall Effect Lec 34 - Intrinsic diffusion and darkens equations. Lec 35 - Tutorial -7	Online
Week 8	:	**Module 5 – Kinetic Simulations** Lec 36 - Introduction to CALPHAD Lec 37 - Introduction to Thermocalc and DICTRA Lec 38 - Thermodynamic and kinetic databases Lec 39 - Homogenization, moving boundary problems. Lec 40 - Tutorial - 8	Online
Week 9		**Module 6 – Diffusion Measurement Techniques** Lec 41 - Radiotracer diffusion Lec 42 - SIMS and EPMA Lec 43 - Mechanical spectroscopy Lec 44 - Nuclear & Electrical methods Lec 45 - Tutorial-10	Online

Week 10		**Module 7 – High diffusivity paths** Lec 46 - Grain boundary structure and fisher model Lec 47 - Kinetic regime of grain boundary diffusion Lec 48 - Dislocation pipe diffusion Lec 49 - Diffusion in nanocrystalline materials Lec 50 - Tutorial-11	Online
Week 11		**Module 8 – Diffusion in important class of materials** Lec 51 - Diffusion in metallic alloys-1 Lec 52 - Diffusion in metallic alloys-2 Lec 53 - Diffusion in semiconductors-1 Lec 54 - Diffusion in semiconductors-2 Lec 55 - Tutorial -12	Online
Week 12		Lec 56 - Diffusion in ionic solids-1 Lec 57 - Diffusion in ionic solids-2 Lec 58 - Diffusion in glasses-1 Lec 59 - Revision of important concepts Lec 60 - Tutorial -13	Online

TA Details			
	:	Teaching Assistant 1	Teaching Assistant 2
Name	:	Ms. Bhawna Yadav	
Department	:	MSME	
Email ID	:	ms21resch01002@iith.ac.in	
Mobile Number	:	9424401710	
Currently pursuing degree	:	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: **Module #5** is 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: **Module #6** – 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: **Module #7**– 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: **Module #8** – 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 **(Module#2 and #3)** 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.