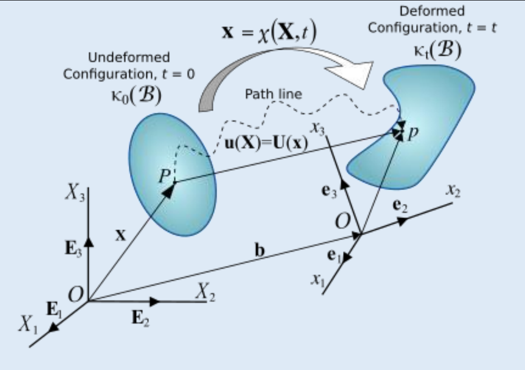
Under the aegis of GIAN

A Course on Continuum Mechanics

(25^{th} May – 3^{rd} June 2023)



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National Centre for Disaster Mitigation & Mgt.

Jointly with

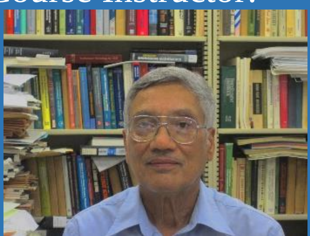
Department of Mechanical Engineering

Malaviya National Institute of Technology Jaipur (Rajasthan)

J.L.N. Marg, Malaviya Nagar, Jaipur, Rajasthan -302017

Website: www.mnit.ac.in

Overview	In continuum mechanics we study physics and mathematical descriptions of deforming continuous media at macroscale i.e. at continuum scale. In such study we do not consider the behavior of matter at smaller scales such as molecular, atomic, or subatomic scales. With the assumption of thermodynamic equilibrium in the deforming continua the study of continuum mechanics provides thermodynamic framework consisting of conservation and balance laws and associated constitutive theories for solid continua as well as fluent continua that describe the physics of evolution of these continua when they are disturbed. In engineering terms, the mathematical model for thermoelastic solids, thermoviscoelastic solids with and without memory, both compressible and incompressible, Newtonian and generalized Newtonian compressible and incompressible fluids (liquids and gases), polymeric fluids, and the associated constitutive theories are within the scope of study in continuum mechanics course proposed here. Thus, this course addresses mechanics of continua without any specific bias to solids, liquids, or gases, hence the material in the course consists of higher-level presentations of concepts and principles but sufficient clarity and details for specific applications.
Objectives of the course	• To study and understand the fundamentals of continuum mechanics applicable to all deforming continua, both solids and fluids, compressible as well as incompressible deforming continua in thermodynamic equilibrium. • To understand and derive/develop the mathematical framework, referred to as thermodynamic framework, of desired physics and associated constitutive theories for solid and fluent continua under finite deformation, finite strains, and finite strain rate considerations.
Course duration	• Duration: **25^{th} May – 3^{rd} June 2023** • Total Contact Hours: 40 hours: 4-hour lectures/day • Mode of delivery: OFFLINE

Course contents	Einstein, index, and matrix notations, and basic operations using these notations, change of frame, transformations, concept and representation of tensors, tensor operations, tensor calculus, covariant and contravariant bases and transformations, transformation of tensors, invariants of tensors, Hamilton-Cayley theorem, kinematics of motion, deformation and their measures, Lagrangian and Eulerian descriptions, covariant and contravariant measures of strains in Lagrangian and Eulerian descriptions, invariants of strain tensors, physical meaning of strain tensors, polar decomposition, definition and measures of stresses, Cauchy stress tensor, first and second Piola-Kirchhoff stress tensors, Jaumann stress tensors, rate of deformation, strain rate measures, spin tensors, convected time derivatives of stress and strain tensors, conservation and balance laws in Lagrangian and Eulerian descriptions for finite deformation, finite strain, and finite strain rate, general considerations in the derivations of constitutive theories, ordered rate constitutive theories for thermoelastic solids and thermoviscoelastic solids with and without memory for compressible and incompressible cases, ordered rate constitutive theories for thermofluids and thermoviscoelastic fluids both compressible and incompressible, Maxwell, Oldroyd-B, and Giesekus constitutive models, ordered rate theories for hypoelastic solids, complete mathematical models with thermodynamic relations, principle of virtual work, and an introduction to non-classical continuum theories (NCCT)
Who should attend the course	The course material is intended for the graduate students (B.Tech./M.Sc./M.Tech./Ph.D.) and faculty members from academic institutions and technical institutions, the engineers, researchers, and scientists in physical sciences and applied mathematics interested in having a thorough understanding of principles and concepts that are essential in the study of deforming continuous media at macroscale by constructing the mathematical descriptions of the desired physics so that the behavior of the associated physical systems can be studied through the use of mathematical descriptions.
Course Fees	The participation fees (excluding onetime GIAN Portal Registration fee of Rs 500/-, and food and accommodation charges) for taking the course is as follows: • Participants from abroad: US$50 • Industry/Research Organizations: Rs. 3000 /- • Faculty from Indian academic Institutions: Rs.1500 /- • Research Scholars and students: Rs. 500/-
Registration date and Mode of fee payment	Participants are required to transfer the registration amount through NEFT/RTGS by ***15th May, 2023*** in the following account of **Registrar (Sponsored research) MNIT Jaipur** **Account no: 676801700388; Bank name: ICIC bank ltd. IFCS code: ICIC0006768** **Branch name: MREC Branch, Malaviya National Institute of Technology Jaipur , J.L.N. Marg, 302017** Please email the transaction details and the signed registration form by ***15th May, 2023*** to Dr. Dinesh Kumar at **dkumar.mech@mnit.ac.in**
Course Instructor:  Prof Karan Surana	Karan S. Surana, born in India, went to undergraduate school at Birla Institute of Technology and Science (BITS), Pilani, India, and received a B.E. degree in Mechanical Engineering in 1965. He then attended the University of Wisconsin, Madison, where he obtained M.S. and Ph.D. degrees in Mechanical Engineering in 1967 and 1970, respectively. He worked in industry, in research and development in various areas of computational mechanics and software development, for fifteen years: SDRC, Cincinnati (1970–1973), EMRC, Detroit (1973–1978); and McDonnell-Douglas, St. Louis (1978–1984). In 1984, he joined the Department of Mechanical Engineering faculty at the University of Kansas, where he is currently the Deane E. Ackers University Distinguished Professor of Mechanical Engineering. His areas of interest and expertise are computational mathematics, computational mechanics, and continuum mechanics. He is the author of over 350 research reports, conference papers, and journal articles. He has served as advisor and chairman of 50 M.S. students and 25 Ph.D. students in various areas of Computational Mathematics and Continuum Mechanics. He has delivered many plenary and keynote lectures in various national and international conferences

	and congresses on computational mathematics, computational mechanics, and continuum mechanics. He has served on international advisory committees of many conferences and has co-organized mini-symposia on k-version of the finite element method, computational methods, and constitutive theories at U.S. National Congresses of Computational Mechanics organized by the U.S. Association of Computational Mechanics (USACM). He has organized mini-symposium on classical and non-classical continuum mechanics at SES (Society of Engineering Science). He is a member of the International Association of Computational Mechanics (IACM) USACM, SES, and a fellow and life member of ASME. Dr. Surana's most notable contributions include: large deformation finite element formulations of shells, the k-version of the finite element method, operator classification and variationally consistent integral forms in methods of approximations for BVPs and IVPs, and ordered rate constitutive theories for solid and fluent continua. His most recent and present research work is in non-classical continuum theories for solid and fluent continua and associated constitutive theories. He is the author of recently published textbooks: Advanced Mechanics of Continua, CRC/Taylor & France, The Finite Element Method for Boundary Value Problems: Mathematics and Computations, CRC/Taylor & Francis, The Finite Element Method for Initial Value Problems: Mathematics and Computations, CRC/Taylor & Francis, and Numerical Methods and Methods of Approximation in Science and Engineering, CRC/Taylor & Francis. You may reach him at: **kssurana@ku.edu.**
Course Coordinators:  Prof. S. D. Bharti  Dr. Dinesh Kumar	Prof. S. D. Bharti, B.E. (Civil), M. Tech. (Structural Engineering) and Ph.D. (Earthquake Engineering) is a Professor in the Department of Civil Engineer, Malaviya National Institute of Technology Jaipur-302017 (India). His areas of research interest are Seismic response control of civil structures, Earthquake Resistant Design of Steel Structures and Seismic rehabilitation and retrofitting of structures. He has guided more than 20 students for their Ph.D. and M.Tech. theses, and published more than 30 research papers in refereed international journals and conferences. Currently, leading a research project entitled "Indigenous design development of base isolation system for seismic hazard mitigation", in collaboration with Indian Institute of Technology Delhi and an Industry collaborator. Under the project, an indigenously design and manufacture elastomeric Base Isolation system for application in building in India has been set up and it is one of the National test facilities in India for dynamic characterization base isolation. You may reach him at: **sdbharti@mnit.ac.in**. Dr. Dinesh Kumar, B.E. (Mech.Engg.), M.E. (Mech. Engg.), Ph.D (BITS Pilani) is presently working as an Associate Professor in the Mechanical Engineering Department of Malaviya National Institute of Technology (MNIT) Jaipur. Prior to joining MNIT Jaipur in 2012, he worked in Birla Institute of Technology & Science (BITS), Pilani India for over 7 years. His current teaching interests are in the areas of Solid Mechanics, Continuum Mechanics, Fracture Mechanics and Finite Element Analysis and Mechanics of Composites, and carrying out research in the areas of Failure and Strength Analysis of Composite Laminates and FGM using Finite Element Methods and Multi-scale and Molecular simulation, Phase Field Modeling of Failures. He has guided 4 Ph.Ds. and nearly 20 M.Tech. theses and published more than 35 research papers in National and International Journals and Conferences of high repute. You may reach him at: **dkumar.mech@mnit.ac.in.**
Accomodation	Limited accommodation in the Institute Hostels/Guest Houses may be available on payment basis on prior request, subject to the availability OR otherwise participants will have to make their own stay arrangements.
Contact details	***Prof. S. D. Bharti:*** Email: **sdbharti@mnit.ac.in;** Mobile: 09549654196. ***Dr. Dinesh Kumar:*** Email: **dkumar.mech@mnit.ac.in;** Mobile: 09549654562.

GLOBAL INITIATIVE OF ACADEMIC NETWORKS

सत्यमेव जयते

Course Schedule

Day 1: May 25, 2023 (Thursday)
Lecture 1 : 9:00 AM to 10:00 AM (IST)
Concepts and mathematical preliminaries. Notations and basic operations.
Lecture 2 : 10.20 AM to 11.20 AM (IST)
Change of frames, transformations, concepts and representations of tensors, tensor operations, and tensor calculus.
Lecture 3 : 3:00 PM to 4:00 PM (IST)
Invariants of tensors, Hamilton-Cayley theorem, differential calculus of tensors, some useful relations
Lecture 4/ Tutorial: 4.20 PM to 5:20 PM (IST)
Discussion, examples, and problem solutions
Day 2: May 26, 2023 (Friday)
Lecture 1 : 9:00 AM to 10:00 AM (IST)
Description of motion, Lagrangian and Eulerian descriptions, material derivatives, displacements, velocities, and accelerations in Lagrangian and Eulerian descriptions
Lecture 2 : 10.20 AM to 11.20 AM (IST)
Coordinate systems and bases, covariant and contravariant bases, strain measures in these bases in Lagrangian and Eulerian descriptions, change in strain measures due to rigid rotation of frames
Lecture 3 : 3:00 PM to 4:00 PM (IST)
Invariants of strain tensors, physical meaning of strain measures, polar decomposition of deformation Jacobian, principal stretches, strain measures in principal stretches, deformation of areas and volumes
Lecture 4 / Tutorial: 4.20 PM to 5:20 PM (IST)
Discussion, examples, and problem solutions
Day 3: May 27, 2023 (Saturday)
Lecture 1 : 9:00 AM to 10:00 AM (IST)
Stress measures for infinitesimal deformation, Cauchy principle, co- and contravariant Cauchy stress tensors in Lagrangian and Eulerian descriptions, symmetry of Cauchy stress tensor
Lecture 2 : 10.20 AM to 11.20 AM (IST)
Stress measures for finite deformation and finite strain in co- and contravariant bases, Piola-Kirchhoff stress tensors, Jaumann stress measures
Lecture 3 : 3:00 PM to 4:00 PM (IST)
Summary of stress measures, conjugate strain measures, relationships between different measures
Lecture 4 / Tutorial: 4.20 PM to 5:20 PM (IST)
Discussion, examples, and problem solutions
Day 4: May 28, 2023 (Sunday)
Lecture 1 : 9:00 AM to 10:00 AM (IST)
Rate of deformation in Eulerian and Lagrangian descriptions, decomposition of velocity gradient tensor and physical meanings, vorticity tensor
Lecture 2 : 10.20 AM to 11.20 AM (IST)

Material derivative of the Jacobian of deformation, rate of change of volume, stress and strain measures for convected time derivatives, convected time derivative of Cauchy stress tensor for compressible and incompressible matter
Lecture 3 : 3:00 PM to 4:00 PM (IST)
Convected time derivatives of strain tensor, conjugate pairs of convected stress and strain measures, objectivity of convected time derivatives
Lecture 4 / Tutorial: 4.20 PM to 5:20 PM (IST)
Discussion, examples, and problem solutions
Day 5: May 29, 2023 (Monday)
Lecture 1 : 9:00 AM to 10:00 AM (IST)
Conservation and balance laws in Eulerian description, introduction, mass density, transport theorem, conservation of mass for compressible and incompressible continua, balance of linear and angular momenta
Lecture 2: 10.20 AM to 11.20 AM (IST)
First and second laws of thermodynamics in Eulerian description: energy equation and entropy inequality, complete summary of conservation and balance laws
Lecture 3 : 3:00 PM to 4:00 PM (IST)
Conservation and balance laws in Lagrangian description, introduction, conservation of mass, balance of linear and angular momenta
Lecture 4 / Tutorial: 4.20 PM to 5:20 PM (IST)
Discussion, examples, and problem solutions
Day 6: May 30, 2023 (Tuesday)
Lecture 1 : 9:00 AM to 10:00 AM (IST)
First and second laws of thermodynamics in Lagrangian description: energy equation and entropy inequality, complete summary of conservation and balance laws
Lecture 2 : 10.20 AM to 11.20 AM (IST)
General considerations in the constitutive theories for solid and fluent continua, different approaches and philosophies
Lecture 3 : 3:00 PM to 4:00 PM (IST)
Ordered rate constitutive theories for thermoelastic solids (finite deformation, finite strain) using entropy inequality, material coefficients
Lecture 4 / Tutorial: 4.20 PM to 5:20 PM (IST)
Discussion, examples, and problem solutions
Day 7: May 31, 2023 (Wednesday)
Lecture 1 : 9:00 AM to 10:00 AM (IST)
Strain energy density function and Taylor series expansion approaches in constitutive theories for thermoelastic solids, discussion of various approaches
Lecture 2 : 10.20 AM to 11.20 AM (IST)
Ordered rate constitutive theories for thermoviscoelastic solids without memory using Helmholtz free energy density
Lecture 3 : 3:00 PM to 4:00 PM (IST)
Ordered rate constitutive theories for thermoviscoelastic solids without memory using Gibbs potential, discussion of the two approaches
Lecture 4 / Tutorial: 4.20 PM to 5:20 PM (IST)
Discussion, examples, and problem solutions
Day 8: June 1, 2023 (Thursday)
Lecture 1 : 9:00 AM to 10:00 AM (IST)

Ordered rate constitutive theories for thermoviscoelastic solids with memory using Helmholtz free energy density
Lecture 2 : 10.20 AM to 11.20 AM (IST)
Ordered rate constitutive theories for thermoviscoelastic solids with memory using Gibbs potential, discussion of the two approaches
Lecture 3 : 3:00 PM to 4:00 PM (IST)
Ordered rate constitutive theories for thermofluids (compressible and incompressible): Newtonian fluids, material coefficients
Lecture 4 / Tutorial: 4.20 PM to 5:20 PM (IST)
Discussion, examples, and problem solutions
Day 9: June 2, 2023, 2022 (Friday)
Lecture 1 : 9:00 AM to 10:00 AM (IST)
Ordered rate constitutive theories for thermofluids (compressible and incompressible): generalized Newtonian fluids, material coefficients
Lecture 2 : 10.20 AM to 11.20 AM (IST)
Ordered rate constitutive theories for polymeric fluids (compressible and incompressible): general derivation
Lecture 3 : 3:00 PM to 4:00 PM (IST)
Derivation of Maxwell model, Oldroyd-B model, Giesekus model, discussion of limitations of currently used theories
Lecture 4 / Tutorial: 4.20 PM to 5:20 PM (IST)
Discussion, examples, and problem solutions
Day 10: June 3, 2023 (Saturday)
Lecture 1 : 9:00 AM to 10:00 AM (IST)
Complete mathematical models for solid and fluent continua
Lecture 2 : 10.20 AM to 11.20 AM (IST)
Thermodynamic relations to augment complete mathematical models
Lecture 3 : 3:00 PM to 4:00 PM (IST)
Principle of virtual work and its relationship to balance laws
Lecture 4 / Tutorial: 4.20 PM to 5:20 PM (IST)
Discussion, examples, and problem solutions

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(25th May – 3rd June 2023)

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Registration form*

Name (In Block Letters): ………………………………………………………………………

Participant's Category: ………………………………………………………………………
(i.e., Abroad/Industry or Research Organization/ Faculty/Student or Research scholars)

Qualification: ………………………………………………………………………

Institution/ Organization: ………………………………………………………………………

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Email address: ………………………………………………………………………

Mobile No: ………………………………………………………………………

Payment details:
Transaction No:……………………………………
Date:……………………………………………..
Bank Name:……………………………………..
Amount:…………………………………………

Signature of the Applicant:

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* Kindly mail the scanned copy of the duly filled registration form, along with the snapshot of transaction made to: dkumar.mech@mnit.ac.in.