Indian Institute of Technology, Kanpur

Proposal for Course Revision

1. Course Number: ME621

2. Course Title: Introduction to Solid Mechanics

3. Per Week Lectures: 3L + 0T + 0P. Credits: 9. Duration: Full Semester

4. Proposing Department: Mechanical Engineering

   Other departments which may be interested in the course: AE

5. Proposing Instructors: Anurag Gupta, Ushasi Roy, P. Venkitanarayanan

6. Course description

A) Objectives:

ME621 is a compulsory foundational course for incoming graduate students in solid mechanics and for the proposed postgraduate programme in computational mechanics. The course develops an understanding of deformation, stress, balance laws, constitutive behaviour, and the formulation of boundary-value problems. It prepares students to approach unfamiliar problems with sound mechanical reasoning and to pursue advanced study in solid and computational mechanics. The course aims to cultivate an appreciation of the subject through careful examination of assumptions, physical interpretation, and the limits of models.

Linear isotropic elasticity provides the main working framework. Selected analytical solutions illustrate the structure of the theory and provide benchmarks for checking predictions. Thermoelasticity and linear viscoelasticity extend this foundation through thermal eigenstrain and material memory. An expository field-coupling module introduces magnetoelasticity, with emphasis on formulating a new problem using familiar principles.

B) Course outline:

The course comprises 40 lectures of 50 minutes each. Every module ends with one supervised in-class problem-solving session (of around 30-50 minutes). In the following, a brief description of contents in each module is followed by suggestions (in smaller font) for the supervised problem-solving session. The instructor can choose a problem from the suggestions according to her/his taste.

Module 1 Deformation and compatibility (5 lectures)

Tensor notation and calculus through mechanical examples; reference and deformed configurations; deformation gradient; finite and infinitesimal strain; physical interpretation; principal strains; compatibility.

Use an affine displacement field to identify normal and shear strains, principal directions, and changes of lengths and angles. Compare an infinitesimal rotation with a finite rigid rotation to expose the limits of linearised strain. Give a simple planar strain field and ask whether it is compatible and whether a displacement can be recovered locally. Discuss the role of domain topology when interpreting local compatibility.

Module 2 Stress and balance laws (4 lectures)

Traction and Cauchy stress; interpretation and principal stresses; linear and angular momentum balances; assumptions behind stress symmetry; equilibrium and the role of inertia.

For a given stress tensor, determine traction on differently oriented planes and interpret normal and shear components. Use a polynomial stress field to test equilibrium and infer required body forces. Check the global force and moment balance of boundary tractions. Ask what assumptions permit a symmetric Cauchy stress and when neglect of inertia is appropriate.

Module 3 Constitutive modelling (4 lectures)

Isotropic linear elasticity; elastic constants; stress power and stored energy; positive definiteness; Mechanical work, heat, and internal energy; distinction between energy conservation and dissipation; entropy and Helmholtz free energy at an introductory level. Constitutive potentials and their role in elastic and coupled material response.

Compare uniaxial stress with uniaxial strain in the same isotropic material. Separate volumetric and distortional responses and examine positive strain energy and admissible elastic constants. Use loading and unloading paths to distinguish elastic storage from dissipation.

Module 4 Formulating an elastic problem (5 lectures)

Strong formulation and Navier equations; displacement and traction boundary conditions; virtual work and weak formulation; rigid-body modes; uniqueness and superposition.

Formulate an elastic body with mixed boundary conditions and identify missing supports, rigid-body motions, or unbalanced prescribed tractions. Derive the weak form of an axially loaded bar and then extend the reasoning to a small-strain solid. Illustrate the usefulness of uniqueness and superposition using a simple problem.

Module 5 Reductions and selected exact solutions (4 lectures)

Plane stress, plane strain, anti-plane shear and axisymmetry; validity of reductions; selected cylinder problems.

Use a pressurised thick cylinder to compare plane-strain and free-end or closed-end idealisations. Consider simple plane problems and illustrate their validity with respect to the full 3-D problem. Ask students to check assumptions and boundary conditions before evaluating stresses.

Module 6 Stress concentrations and singularities (5 lectures)

Circular-hole fields; stress concentration; singular wedge problems; physical interpretation of singularities.

Supply selected expressions for stresses around a circular hole and ask students to check traction-free conditions, far-field behaviour, and stress concentration. Compare a smooth hole with a sharp crack using a supplied near-tip field. Examine a sequence of computed crack-tip stresses as the mesh is refined and discuss meaningful quantities for comparison.

Module 7 Thermoelasticity (4 lectures)

Thermal eigenstrain, free-expansion and constraints, compatibility and residual stress, all with prescribed temperature fields; heat conduction and an introduction to coupled thermal-mechanical formulations.

Revisit an elastic bar under uniform heating, first with free ends and then with fixed ends or an elastic support. Extend the example to a bonded pair with different thermal expansion coefficients. Ask when thermal eigenstrain can be accommodated without stress; spatial variation alone is insufficient to establish that stress must occur. Formulate a simple steady conduction problem and distinguish a prescribed temperature field from a coupled thermal-mechanical calculation.

Module 8 Linear viscoelasticity (4 lectures)

Creep and relaxation; simple spring-dashpot models and a standard linear solid; constitutive evolution and history; initial conditions; dissipation and characteristic times.

Apply a step strain or step stress to a standard linear solid. Sketch the response before solving, identify the correct initial conditions, and examine short- and long-time limits. Reuse the restrained-bar setting to study reaction relaxation under fixed extension. Compare models that recover their original length with models permitting persistent flow and relate their responses to storage and dissipation.

Note: Use the standard linear solid as the main example for understanding material memory, creep, relaxation, and dissipation. Derive its constitutive evolution from the spring–dashpot arrangement and examine initial conditions and short- and long-time behaviour. Other elementary models may be used briefly to clarify differences in recovery and persistent flow. The emphasis should remain on interpreting time-dependent response and formulating a simple initial-value problem. A one-dimensional differential-equation treatment is sufficient for the principal development.

Module 9 A field coupled solid (5 lectures)

Magnetoelastic modelling using a supplied consistent constitutive potential; magnetic field variables and magnetostatic equations; mechanical and magnetic boundary conditions; prescribed-field and coupled formulations; limiting cases and verification.

Use a magnetically responsive bar or simple layer with a supplied small-strain constitutive potential and clearly defined magnetic variables. Compare free and restrained responses under a prescribed field. Then identify the additional unknowns, magnetostatic equations, and interface conditions required when the field must also be solved. State the energy convention and traction treatment consistently, including the surrounding magnetic field where required; avoid double-counting magnetic forces.

Note: Use one simple coupled system to demonstrate how the established formulation process extends to unfamiliar physics. For magnetoelasticity, work with a supplied constitutive potential, explicitly defined magnetic variables, and a consistent treatment of energy and boundary tractions. Develop a prescribed-field example before identifying what changes when the magnetic field must also be solved. A simple geometry and one constitutive model are sufficient. The instructor may choose another coupling while retaining the same objectives of formulation, interpretation, and verification.

General remarks

1. A common problem can be used across modules: A restrained bar can be revisited under elastic loading, thermal expansion, viscoelastic relaxation, and a supplied magnetic coupling. Keep the geometry familiar and change one physical ingredient at a time. Ask students to state which parts of the formulation remain valid and which must change.

2. Emphasise the recurring formulation of identify fields, kinematics, balances, constitutive assumptions, boundary and initial conditions.

3. Mathematical preliminaries (tensor algebra/calculus, integral theorems) should be developed alongside their use. Targeted refresher exercises can be given.

4. Connection with computation. Teach the weak form and distinguish displacement conditions from traction conditions. Use occasional numerical plots or short demonstrations to examine modelling choices, convergence, and near-incompressibility.

5. AI usage. Allow AI, symbolic tools, and code during preparation, subject to a clear policy. Students remain responsible for checking outputs and acknowledging substantive assistance in submitted preparation work. Give all students the same flawed derivation or numerical result to critique when practicing diagnosis. Grades should rest on supervised work and individual explanation.

Assessment policy

Supervised module sessions (50%).

Mid-term grand viva (25%).

End-term grand viva (25%).

The supervised sessions are to be followed with detailed assignments (which can be done in groups). The grading should be based on the work that the students do in class.

The vivas will include giving problems sets a day prior to the oral examination. The examination, tentatively around 15 mins in duration per student, should assess student's understanding of the problem, the solution methodology, the underlying assumptions, and simple extensions.

C) Prerequisites: None

D) Short Summary for Including in the Courses of Study Booklet

Deformation and compatibility, Stress and balance laws, Constitutive modelling, Linear Elasticity, Singular Problems, Thermoelasticity, Linear viscoelasticity, Field coupled solid.

7. References

1. J. R. Barber, Elasticity, 4th edition, Springer. (Modules 3 to 7).

2. W. S. Slaughter, The Linearized Theory of Elasticity, Springer. (Modules 1 to 5).

3. L. Anand and S. Govindjee, Continuum Mechanics of Solids, Oxford. (Modules 3, 7 to 9).

Additional reading prescription may be needed in the last three modules as per the preference of the instructor.

8. Any other remarks: nil

Dated: 04-Nov-2026 Proposer:_____

Dated:_____ DPGC Convener:_____

The course is approved / not approved

Chairman, SPGC

Dated:_____