Course Contents

Topic	**Contents**
0. Introduction and overview	Overview of course structure: topics, references, computer lab classes. How to model fracture: fracture mechanics (sharp cracks) vs damage mechanics (diffuse cracks).
1. Linear elastic fracture mechanics (LFEM)	Basic concepts in linear elastic fracture mechanics: Griffith energetic approach, fracture toughness; crack tip stress fields; energy release rate; stress intensity factors, J-integrals, interaction integrals, the virtual crack closure technique.
2. Discontinuous computational models	Computational models based on sharp cracks (jumps in the displacement field): 2.1 The cohesive zone model (CZM): traction-separation laws; crack path consists of element edges / faces. 2.2 The extended finite element method (XFEM): jump enrichment of the displacement field; crack path across elements. 2.3 Generalized FEM for LEFM: Conditioning control; Application examples.
3. Continuous computational models	Computational models based on diffuse cracks (bands of strain concentration): 3.1 Continuum damage models: mesh sensitivity of local damage models; need to regularise softening; integral-type nonlocal models; gradient-enhanced nonlocal damage models. 3.2 Phase-field models: the energetic viewpoint; equilibrium and phase-field equations; tension-compression splits; history variable; staggered algorithmic solution. 3.3 Similarities and differences between damage models and phase-field models
4. Advanced topics	Overview of current research topic in computational fracture mechanics: continuous-discontinuous models; adaptive strategies; multiphysics applications.

Computer Lab component

Numerical Experiment	**Brief Description**
1. The extended/generalized finite element method	Discuss the efficient implementation of XFEM, with emphasis on *i)* handling of enriched degrees of freedom and *ii)* numerical integration on cut elements.
2. Local damage models	Discuss the following aspects: *i)* the monolithic Newton-Raphson solution of the nonlinear system of equations and *ii)* the mesh-sensitivity of local models and the need to regularise softening.
3. Gradient-enhanced models	Discuss the gradient enhancement of a damage model, with emphasis on *i)* the role of the internal length and *ii)* the mesh insensitivity.
4. Phase-field models 1	Discuss the efficient implementation of a phase-field model, with emphasis on i) the role of the internal length and ii) the staggered algorithmic solution.
5. Phase-field models 2	Run an adaptive phase-field code to model crack propagation, branching and merging, to illustrate the need for adaptivity and its impact in reducing computational cost.