Earthquake Source Mechanics — Syllabus

Fridays 14:00–17:00, Sept 2026–Jan 2027 (Salle E409)

Instructors: Harsha S. Bhat, Pierre Dublanchet, Carolina Giorgetti

This course provides an introduction to the physical and mechanical processes governing earthquake generation and seismic radiation. Starting from continuum mechanics and elastodynamics, students develop the mathematical tools needed to describe stress, strain, elastic waves, Green's functions, and seismic sources. The course then examines moment tensors, radiation patterns, seismic moment, source spectra, and kinematic source models. Building on these foundations, it introduces fracture mechanics, friction laws, laboratory observations, and the dynamics of earthquake rupture, including supershear and slow-slip phenomena. Particular attention is given to the energy budget of earthquakes and to the connection between individual earthquake sources and statistical patterns of seismicity. The course combines theoretical developments, classical models, observational evidence, and laboratory experiments to provide a unified framework for understanding the earthquake source process.

	Date	Topic	Instructor
1	Fri 11 Sep 2026	Continuum Mechanics & Math Primer	Harsha
2	Fri 18 Sep 2026	Elastodynamics I: The Wave Equation	Harsha
3	Fri 09 Oct 2026	Elastodynamics II: Green's Functions & Representation Theorem	Harsha
4	Fri 16 Oct 2026	Far-Field Radiation & the Seismic Source	Pierre
5*	Fri 23 Oct 2026	Kinematic Source Models	Pierre
6*	Fri 30 Oct 2026	Fracture Mechanics Fundamentals	Harsha
7	Fri 06 Nov 2026	Friction Laws	Harsha
8	Fri 13 Nov 2026	Laboratory Friction	Carolina
9	Fri 20 Nov 2026	The Dynamic Rupture Problem	Harsha
10	Fri 04 Dec 2026	Supershear Rupture	Harsha
11	Fri 11 Dec 2026	Slow-to-Fast Slip Spectrum	Harsha
12	Fri 18 Dec 2026	Energy Budget & Statistical Seismicity	Pierre
13	Fri 08 Jan 2027	Laboratory Earthquakes	Carolina & Harsha

- Vacances de la Toussaint

Lecture 1- Continuum Mechanics & Math Primer (Fri 11 Sep 2026, HARSHA)

- Why continuum mechanics matters for understanding earthquake sources (approx 10-15 mins)
- Vectors & tensors — index notation, coordinate transforms, isotropic tensors (approx 30-35 mins)
- Stress — traction vector, Cauchy's stress tensor, symmetry, principal stresses (approx 30-35 mins)
- Break (15-20 mins)
- Strain — displacement field, infinitesimal strain tensor, compatibility (approx 25-30 mins)
- Constitutive law — Hooke's law, Lamé parameters, a first look at Navier's equation (approx 20-25 mins)
- Wrap up and summarize (approx 5-10 mins)

Lecture 2- Elastodynamics I: The Wave Equation (Fri 18 Sep 2026, HARSHA)

- Quick recap of Navier's equation from last time (approx 10-15 mins)
- Getting to the elastic wave equation from momentum balance and Hooke's law (approx 30-35 mins)
- P & S waves — Helmholtz decomposition, wave speeds α and β (approx 25-30 mins)
- Break (15-20 mins)
- Plane waves — solutions, polarization, particle motion (approx 30-35 mins)
- Energy density & flux in elastic waves, a first look at geometrical spreading (approx 20-25 mins)
- Wrap up and summarize (approx 5-10 mins)

Lecture 3- Elastodynamics II: Green's Functions & Representation Theorem (Fri 09 Oct 2026, HARSHA)

- Quick recap (approx 10-15 mins)
- The point-force Green's function in a full space — near, intermediate, and far-field terms (approx 30-35 mins)
- Betti's reciprocal theorem (approx 25-30 mins)
- Break (15-20 mins)
- Deriving the representation theorem, and the fault as a displacement discontinuity (approx 30-35 mins)
- The moment tensor and the equivalent body-force picture, the double-couple (approx 20-25 mins)
- Wrap up and summarize (approx 5-10 mins)

Lecture 4- Far-Field Radiation & the Seismic Source (Fri 16 Oct 2026, PIERRE)

- Quick recap of the moment tensor from last time (approx 10-15 mins)
- Far-field P/S radiation patterns from a double couple (approx 25-30 mins)
- Seismic moment M0, and how it relates to magnitude scales (approx 25-30 mins)
- Break (15-20 mins)
- The source time function and moment-rate function (approx 25-30 mins)
- The omega-squared model — corner frequency, estimating static stress drop (approx 25-30 mins)
- Wrap up and summarize (approx 5-10 mins)

Lecture 5- Kinematic Source Models (Fri 23 Oct 2026, PIERRE)

- Quick recap (approx 10-15 mins)
- Dislocation theory — Steketee, Burridge–Knopoff, static dislocation solutions (approx 25-30 mins)
- The Haskell model — a propagating dislocation source, rise time, rupture velocity, unilateral vs. bilateral rupture (approx 30-35 mins)
- Break (15-20 mins)
- Finite-fault parameterization — slip distributions, multiple time-window representations (approx 25-30 mins)
- A first look at inversion — the forward problem, non-uniqueness, why source inversion is ill-posed (approx 25-30 mins)
- Wrap up and summarize (approx 5-10 mins)

Lecture 6- Fracture Mechanics Fundamentals (Fri 30 Oct 2026, HARSHA)

- Quick recap, and why we're moving from kinematics to dynamics (approx 10-15 mins)
- The Griffith energy balance and energy release rate G (approx 30-35 mins)
- The crack-tip stress field and stress intensity factor K (approx 25-30 mins)
- Break (15-20 mins)
- Fracture energy Gc and the process-zone idea (approx 30-35 mins)
- Static vs. dynamic fracture criteria, the Griffith criterion (approx 20-25 mins)
- Wrap up and summarize (approx 5-10 mins)

Lecture 7- Friction Laws (Fri 06 Nov 2026, HARSHA)

- Quick recap (approx 10-15 mins)
- Coulomb friction — static/kinetic friction, Byerlee's law (approx 25-30 mins)
- Slip-weakening friction — Ida (1972), Palmer–Rice, the critical slip distance Dc, the breakdown zone (approx 30-35 mins)
- Break (15-20 mins)
- Rate-and-state friction — Dieterich, Ruina, the (a–b) parameter, state evolution laws (approx 30-35 mins)
- Stability — a linear stability analysis, nucleation size (approx 20-25 mins)
- Wrap up and summarize (approx 5-10 mins)

Lecture 8- Laboratory Friction (Fri 13 Nov 2026, CAROLINA)

- Quick recap (approx 10-15 mins)
- Break (15-20 mins)
- Wrap up and summarize (approx 5-10 mins)

Lecture 9- The Dynamic Rupture Problem (Fri 20 Nov 2026, HARSHA)

- Quick recap (approx 10-15 mins)
- Setting up the elastodynamic crack problem and the boundary integral idea (approx 25-30 mins)
- The Kostrov self-similar rupture solution (approx 25-30 mins)
- Break (15-20 mins)
- Crack-like vs. pulse-like rupture, Heaton's self-healing pulse (approx 30-35 mins)
- The energy budget — radiated energy, fracture energy, frictional heat, how it all partitions (approx 25-30 mins)
- Wrap up and summarize (approx 5-10 mins)

Lecture 10- Supershear Rupture (Fri 4 Dec 2026, HARSHA)

- Quick recap (approx 10-15 mins)
- Sub-Rayleigh vs. supershear regimes, the limiting speeds — Rayleigh, S, P (approx 25-30 mins)
- The Burridge–Andrews mechanism — daughter-crack nucleation (approx 25-30 mins)
- Break (15-20 mins)
- The critical stress ratio S and Mach-cone radiation (approx 30-35 mins)
- What we've observed (approx 25-30 mins)
- Wrap up and summarize (approx 5-10 mins)

Lecture 11- Slow-to-Fast Slip Spectrum (Fri 11 Dec 2026, HARSHA)

- Quick recap (approx 10-15 mins)
- What we observe — slow-slip events, tremor, LFEs, VLFEs (approx 25-30 mins)
- Rate-and-state in the conditionally stable regime (approx 25-30 mins)
- Break (15-20 mins)
- Mechanisms — near-neutral stability, fluid effects, transition zones (approx 30-35 mins)
- Pulling it together: the slip spectrum, from creep to earthquake (approx 25-30 mins)
- Wrap up and summarize (approx 5-10 mins)

Lecture 12- Energy Budget & Statistical Seismicity (Fri 18 Dec 2026, PIERRE)

- Why we're zooming out, from single events to populations of earthquakes (approx 10-15 mins)
- Pulling the energy budget together — Es, Ef, Eh, Ed, apparent stress, radiation efficiency (approx 30-35 mins)
- How Es is actually estimated from seismograms — energy-moment scaling, energy magnitude, and the uncertainties involved (approx 25-30 mins)
- Break (15-20 mins)
- The Gutenberg-Richter frequency-magnitude relation and the b-value (approx 25-30 mins)
- Omori-Utsu aftershock decay, productivity, a nod to ETAS, and catalog completeness (approx 25-30 mins)
- Wrap up and summarize (approx 5-10 mins)

Lecture 13- Laboratory Earthquakes (Fri 08 Jan 2027, CAROLINA & HARSHA)

- Photoelasticity Experiments
- Break (15-20 mins)
- Triaxial saw-cut experiments

- Wrap up and summarize (approx 5-10 mins)