GPH 542

Physics of Earthquake Source I **(3+0+0) 3**

Course Description

This graduate level course presents a basic study of seismic sources and the fundamentals for the mathematical description of the earthquake process. It introduces techniques necessary for understanding of the moment tensor representation of faulting geometry, the low and high frequency characteristics of seismic waveforms and the basic concept of earthquake magnitude.

Technical Requirements

The student is expected to be familiar with basic concepts of elasticity, linear algebra, vector calculus, integral theorems for vector fields, partial differential equations with particular emphasis to wave equation. Knowledge of basic digital signal processing tools (Fourrier Transform, Digital Signal Processing) are required and MATLAB® will be used intensively troughout the course.

Staff

Instructor:
Prof. Dr. Mustafa AKTAR

Syllabus

Point sources. Near field, far field radiation. Equivalent body forces. Double couple sources. Elastostatic. Elastodynamic. Seismic moment tensor. Radiation pattern. Fault plane solutions. Finite sources. Rupture models. Haskell Source. Source directivity. Source spectrum. Fault geometry and corner frequency. Stress drop, rupture velocity. Magnitude. Energy.

Program

week 1

week 2 **Elastostatic I**
Derivation of basic equation for equilibrium:
Newton Eq. + Hooke's eq. + Displacem/strain + Helmholtz Eq.
Solution to homogeneous wave equation: solenoidal and irrotational fields
PDE for displacement potentials: Poisson Eq.
Solution to Poisson Eq.: Somigliana Tensors

week 3 **Elastostatic II**

Empirical definition of moment F.dx=cte=moment
Static displacement due to Single Couple
Static displacement due to Double Couple
Representing couples or double couples in a matrix form: Moment Tensor
General properties of the Moment Tensor as matrix (sum diag=0, symetric, eig1=0)
Introduction to eigenvalues of the Moment Tensor, coordinate transforms

week 4 **Elastodynamics:**

Inhomogeneous wave equation
Laplace Equation with inhomogeneous terms, PDE for displacement field
Solution to inhomogeneous wave equation: inmpulse in time & spac to general form
Classic Stoke's solution: near field and far field terms
From single force to Single Couple and then to Double Couple, moment rate function
Radiation Patterns terms: P-wave, SV-wave and SH-wave

week 5 **The Seismic Moment Tensor**

What each terms of the moment tensor describes
Obtain moment tensor starting from Tension, pression and nul axis
Green's function for P, SV and SH components
Expressing a moment tensor as sum of elementatry moment tensors ?
Dipoles turns into double couple by 45 degree rotation
What is CLVD
Decomposition of general (non-double-coule) moment tensor

week 6 **Determination of Fault Orientation:**

Body waves: P and S
Focal sphere near the source
Takeoff angles
Stereographic aand Equal area projection

week 7 **Mid-Term Exam**

week 8 **Earthquake Kinamatics and Dynamics, friction**

Coulomb-Mohr Criteria
Byerlee Law
Anderson theory of faulting
Mohr Circle
Static and Dynamic friction
Stick-slip behavior
Stable sliding
Strength of a rock
Stress drop
Slip weakening
Velocity weakening
Failure envelope
Particle velocity
Healing of a fault front
Kostrov and Heaton models for rupture propogation

week 9 **1-D Haskell Source, Directivity effect**

Farfield displacement for point source
Farfield displacement for rectangular source
What is rupture time, presentation as a boxcar function
What is rise time, presentation as a boxcar function

Displacement is the convolution of two boxcars: Trapezoid
Two sources of delay for rectangular seismic source
The delay due to rupture propagation
The delay due to shortening or extension of ray path
Directivity expression as the sum of two delay term

week 10 **The Source Spectrum: corner freq. source size**
Spectrum of a Haskell source: product of two sinc functions
Corner frequencies: rupture time estimation, slip time estimation
Slope of the spectrum
Estimation of spectral parameters : real life exemple
More complicated spectral representations

week 11 **Stress Drop, particle Velocity, Rupture Velocity**
What is stress drop
How the stress drop relates to the fault dimension
Stres drop in intra and inter-plate earthquakes
How does stress drop relates to the seismic moment
How does stress drop relates to particle velocity
How does stress drop relates to rupture velocity

week 12 **Magnitude of Earthquakes**
Local magnitudes (Richter - m_l)
Body wave magnitude (m_b)
Surface wave magnitude (M_s)
How does various magnitude definition relates to spectrum
Magnitude saturation
Moment Magnitude

week 13 **Self-similarity of earthquakes**
Seismic Energy and magnitude
Seismic Energy and moment
Self-similarity
meaning of b-values
estimation of b-values

Readings

<u>Primary Texbook:</u>
Modern Global Seismology
Thorne Lay and T.C. Wallace
ISBN 0-534-37164-7
Academic Press, 1995
(Chapters 2, 8-9)

<u>Additional Readings:</u>
An Introduction to Seismology
Seth Stein and Michael Wysession
ISBN 0-886542-078-5
Blackwell Publishing, 2003

The Complex Faulting Process of Earthquakes

Junji Koyama
ISBN 0-7923-4499-5
Kluwer Academic Publishers, 1997

The Mechanics of Earthquake Faulting
Christopher H. Sholz
ISBN 0-521-33443-8
Cambridge University Press, 1990