Handout No. 1	**Stanford University**
CEE 314 – Computational Poromechanics	**Spring 2020**

COURSE NOTES

Instructor in Charge: Ronaldo I. Borja
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Office Hours: M & W 10:45 – 11:20 am
(or by appointment)

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Books on Reserve (Engineering Library):

1. R. de Boer, Theory of Porous Media, Highlights in the Historical Development and Current State, Springer Verlag, 2000 (one copy).
2. L.E. Malvern, Introduction to the Mechanics of a Continuous Medium, Prentice-Hall, Englewood Cliffs, NJ, 1969 (one copy).
3. T. J. R. Hughes, The Finite Element Method, Prentice-Hall, Englewood Cliffs, NJ, 1987 (two copies).
4. J. Bear, Dynamics of Fluids in Porous Media, Dover Publications, NY, 1972 (two copies).

Notes:

The course deals with the mechanics of porous media focusing on the solid deformation and fluid flow. Porous media are encountered in many areas of engineering and science, including biomechanics, physical chemistry, materials science, geomechanics, geosciences, and petroleum engineering. Some applications include coupled solid deformation and fluid flow in earth structures, and mass transport through soft and hard tissues. We derive the balance laws for saturated and unsaturated porous continua, develop the weak and matrix forms for finite element implementation, and solve boundary-value problems using the finite element software ANSYS.

Homework problem sets will be assigned on a regular basis and will be due one week later. There will be computing assignments. You will need some knowledge of C++, MATLAB, or FORTRAN for some of the homeworks. There will be no exams. The final grade will be calculated from the weighted average of your homework scores.

COURSE OUTLINE

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1. Introduction **March 30**

Concept of volume fraction; particle scale; continuum scale.

*Class Handout

2. Flow Through Porous Media (1 week)

General conservation laws; constitutive assumptions; Darcy's law; Richards equation

*Reference 4, Chapter 4; Class Handout

3. FE Formulation of Transient Fluid Conduction Problems (2 weeks)

Strong and weak forms; Galerkin approximation; matrix problem; solution of elliptic and parabolic systems; time-integration algorithms—stability and accuracy.

*Reference 3, Chapters 2, 7 and 8; Class Handout

4. FE Formulation of Solid Deformation Problems (1 week)

General conservation laws; constitutive assumptions; Hookean and non-Hookean materials; strong and weak forms; Galerkin approximation; matrix problem.

*References 1 and 2; Reference 3, Chapter 2; Class Handout

5. Coupled Solid Deformation-Fluid Flow Problems (1.5 weeks)

Mixed variational principles; time integration for 'mixed' parabolic systems—stability and accuracy; incompressibility constraint; the Lagrange multipliers and penalty methods; stabilized low-order mixed finite elements.

*Reference 4; Class Handout

6. Unsaturated Flow (1 week)

Capillary pressure (matric suction); notion of effective stress in unsaturated porous media; effective permeability; FE formulation.

*Class Handout

7. Nonlinear Systems (1 week)

Solution of nonlinear finite element systems: Newton iteration, modified Newton, preconditioned conjugate gradient techniques, solvers.