COURSE NOTES

Instructor in Charge: Ronnie I. Borja
Terman 244; Tel. 723-3664; E-Mail: borja@stanford.edu
Office Hours: M & W 1:30 – 2:30 pm
(or by appointment)

Course Assistants: Joshua A. White & Pablo F. Sanz
Blume 209; Tel. 725-0380;
E-Mail: joshua.white@ & pfsanz@
Office Hours: TBA

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. O. C. Zienkiewicz, et. al., Computational Geomechanics: With Special Reference to Earthquake Engineering, John Wiley & Sons, NY, 1999 (one copy).
5. J. Bear, Dynamics of Fluids in Porous Media, Dover Publications, NY, 1972 (two copies, **Branner Library**).

Notes:

The course deals with the mechanics of porous media from a computational standpoint. Porous media are relevant to geotechnical engineering, biomechanics, physical chemistry, materials science, geosciences, and petroleum engineering. Some applications include liquefaction of saturated soils and mass transport through soft and hard tissues. We derive balance laws for three-phase continua, with and without inertia effects. Then we develop the weak forms for finite element implementation.

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 these homeworks. There will be a one-hour midterm examination (Friday, May 5) and a take-home final examination. The final grade will be calculated from the following formula: Final Examination: 40%, Mid-Term Examination: 30%, Homework: 30%.

COURSE OUTLINE

---

1. Introduction **April 5**

Concept of volume fraction; continuum scale; particle scale.

*Class Handout

2. Physics of Flow Through Porous Media (1 week)

General conservation laws; constitutive assumptions; Darcy's law.

*Ref. 5, Ch. 4; Class Handout

3. FE Analysis of Classical 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.

*Ref. 3, Chs. 2, 7 and 8; Class Handout

4. FE Analysis of Classical Elastostatics Problems (1 week)

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

*Refs. 1 and 2; Ref. 3, Ch. 2; Class Handout

MID-TERM EXAMINATION **May 5**

5. General Consolidation Theory (1.5 weeks)

Mixed variational principles; time integration for 'mixed' parabolic systems—stability and accuracy; incompressibility constraint; the Lagrange multipliers and penalty methods.

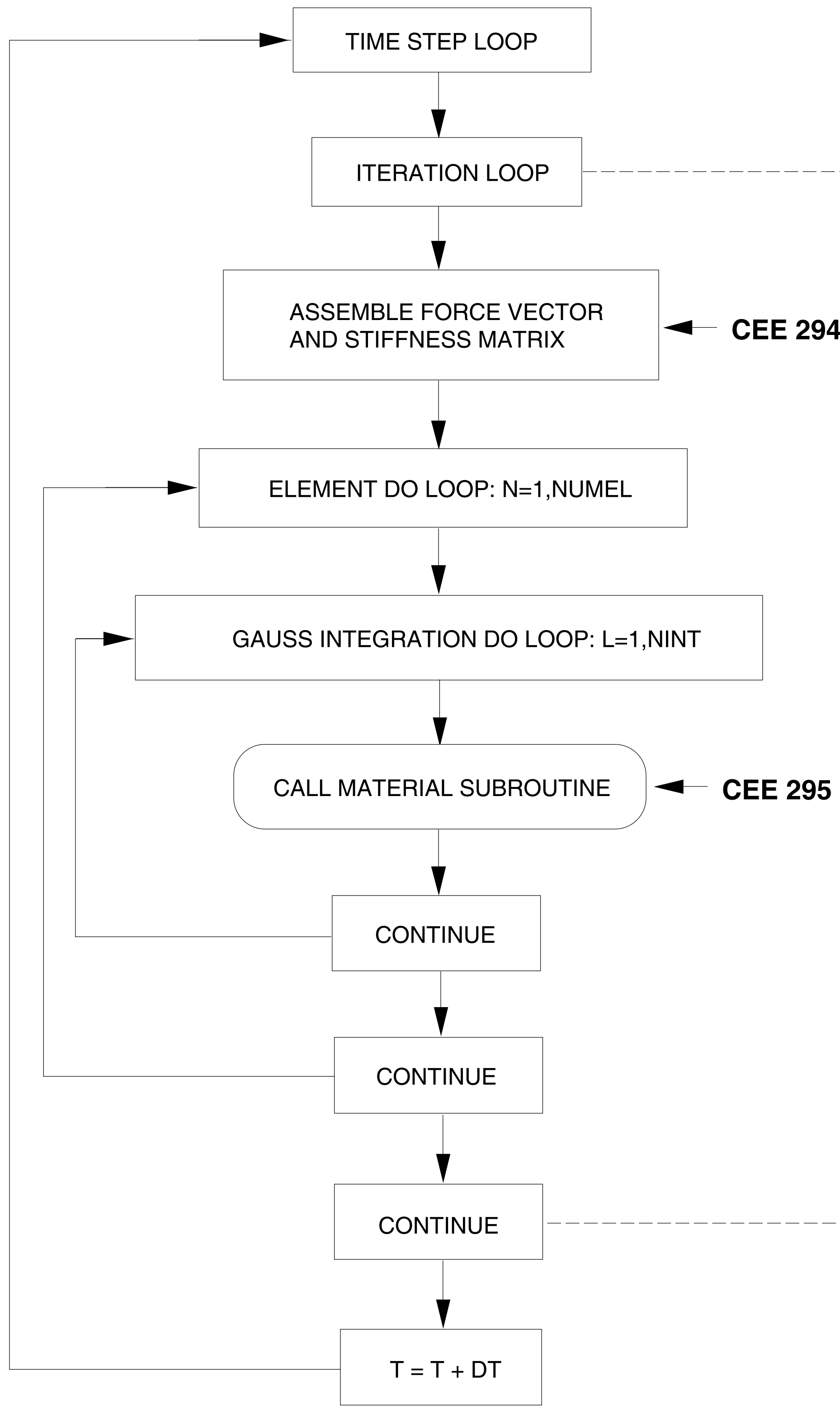
*Ref. 5; Class Handout

6. Dynamics and Wave Propagation in Porous Media (2 weeks)

Wave velocities in porous media; classes of waves; Biot's equation in the dynamic regime; the 'complete' formulation of multiphase dynamics; the $(\boldsymbol{u}, p)$ formulation and its finite element implementation; time-integration for hyperbolic 'mixed' systems.

*Ref. 4; Class Handout

FINAL EXAMINATION **Due June 13**



Structure of a time-domain nonlinear FE program.