Introduction to flow in porous media – 2 credits

Course Number: 224.4039

Lecturer: Dr. Regina Katsman

Office Hours: Monday, 12:00-14:00, Multipurpose Building – Room 261, tel. 048288979, email: katsman@univ.haifa.ac.il

Course Type: Lecture

Course Level: MSc/ PhD

Prerequisites: No

Course Description:

The main objective of the course is to study a single- and two-phase flow of gas, oil and water within porous aquifers, and to define a coupling between them. The following subjects are covered: porous media, phase, phase saturation, permeability, relative permeability, phase compressibility; wettability, capillarity and capillary pressure, interphase phenomena (surface energy, surface tension, adhesion force); Darcy's law and diffusion equation in porous media; steady-state, quasi- steady-state, and transient flow regimes; two-phase flow of gas and oil in wells, flow regimes, flow maps of gas and oil, pressure drop; radial flow and well modeling; modeling, numerical solutions, simulations.

Topics:

1. Definitions: porous media, porosity (total and effective), grain packing, rock compressibility, hydrostatic vs. lithostatic pressure.
2. Fluid properties: phase, component, phase saturation, fluid density, density-pressure relation, fluid compressibility.
3. Fluid properties: gas solubility, mass fraction, fluid viscosity, phase saturation (initial and residual).
4. Interphase phenomena: surface energy, surface tension, interfacial tension, surface curvature and fluids pressure.
5. Interphase phenomena: wettability, capillarity and capillary pressure, Laplace equation for capillary pressure, Young's (contact angle) equation.
6. Interphase phenomena: capillary rise, phase adsorption, imbibitions, drainage, capillary entry pressure.
7. Residual and irreducible saturation, effective saturation, capillary pressure-saturation relations: Brooks - Corey, van Genuchten, scaling.
8. Intrinsic and relative permeability, permeability-saturation relations for wetting and non-wetting phases: Brooks – Corey, Corey, van Genuchten, Naar and Henderson's models, retention curve.
9. Darcy's flow: Darcy's experiment, volumetric flow rate, hydraulic conductivity, hydraulic potential, hydraulic head, pressure head, elevation head, hydrostatic vs. non hydrostatic loading.

10. Darcy's law (single phase): Darcy's velocity, average pore velocity, hydraulic conductivity and permeability, tortuosity, tortuosity-porosity relations, intrinsic permeability by Kozeny, Carman, Fair and Hatch, anisotropy.
11. Mass conservation for a single phase flow in porous media: representative elementary volume, different forms of a conservation equation, incompressible/slightly compressible/ compressible flow, initial and boundary conditions.
12. Two-phase flow of immiscible fluids: basic equations for saturation and pressure, mass conservation equation for each fluid phase, Darcy's velocities for each phase, non-linearity and coupling, initial and boundary conditions.
13. Alternative differential equations for fluid phase conservation: formulation in phase pressure and saturation, average formulation, weighted formulation.
14. General form of transport equation in continuum: advective and diffusive fluxes, Fick's law, particular cases of conservation equation: for a phase in a multiphase flow, for a component in a multi/single phase flow.

Learning Outcomes:

At the end of the course, students will be able to:
1. Analyze transport processes in porous media.
2. Build reservoir simulators.
3. Simulate single- and two-phase flows in reservoirs.

Requirements: Attendance, two projects.

Grading: Passed – 65%, with grade.

Reading List:

1. Pinder, G.F., Gray, W.G., 2008. Essentials of multiphase flow and transport in porous media. John Wiley & Sons, Inc., Hoboken, New Jersey.
2. Chen, Z., 2007. Reservoir Simulation Mathematical Techniques in Oil Recovery. Society for Industrial and Applied Mathematics, Philadelphia.

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