جامعة الملك عبدالله للعلوم والتقنية
King Abdullah University of Science and Technology

# Course Syllabus: Fluid Mechanics - ME 200A

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| **Division** | Physical Science and Engineering Division |
| **Course Number** | ME 200A |
| **Course Title** | Fluid Mechanics |
| **Academic Semester** | Fall |
| **Academic Year** | 2018/2019 |
| **Semester Start Date** | 08/26/2018 |
| **Semester End Date** | 12/11/2018 |
| **Class Schedule** (Days & Time) | 04:00 PM - 05:30 PM \| Sun Wed |

## Instructor(s)

| Name | Email | Phone | Office Location | Office Hours |
|---|---|---|---|---|
| Gaetano Magnotti | GAETANO.MAGNOTTI@KAUST.EDU.SA | +966128082874 | 4335, 5, Al-Kindi (bldg. 5) | To be determined with students. |

## Teaching Assistant(s)

| Name | Email |
|---|---|
| None | N/A |

## Course Information

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| **Comprehensive Course Description** | This course is an introductory graduate level basic course in Fluid Dynamics. It starts by introducing the continuum hypothesis. Then we introduce surface tension and the boundary conditions at a free surface, in terms of the Young-Laplace equation. We then introduce the capillary length and discuss wetting and the contact line, along with superhydrophobicity and the capillary rise in a small tube. Streamlines and other flow-lines are then described and equation derived to describe them. We then introduce the concept of convective acceleration and the difference between Eulerian and Lagrangian description of the flow. The concervations laws of mass, momentum and energy will be derived using the Reynolds Transport Theorem. In this way we will derive the continuity equation as well as the Navier-Stokes equations. Following this we derive specialized forms, like the Bernoulli equation, the inviscid Euler equations, before finding exact solutions of the Navier-Stokes equations, when the flow is unidirectional. This includes the flow down an inclined plane, the First and Second Stokes problems of a solid plate suddenly moving tangentially. We introduce dimensional analysis using the Buckingham Pi-theorem and show various self-similar phenomena. Other exact solutions are the flow in convergent or divergent channel. We then introduce the velocity potential and the streamfunction. This includes the complex potential and Cauchy-Riemann conditions. Then we give the basic potential flow solutions of source, sink, point vortex, doublet, flow in a sector and the flow around a circular cylinder. Then we calculate the lift on a rotating cylinder and introduce the d'Alemberts paradox and the Blasius drag laws. We mention conformal mappings and the Schwarz-Christoffel transformation. We use potential flow to explain the collapse of cavitation bubbles. Then we derive the vorticity equations, explain the Kelvin's circulation theorem and the Biot-Savart law and apply these to the motion of a vortex ring. Explain the importance of stretching and tilting terms in the vorticity dynamics. We then explain bubble dynamics, oscillations, rising speed under buoyancy, followed by general treatment of waves on a liquid surface. Derive the dispersion relationships for both gravity and capillary waves, in deep and shallow water. Introduce the concepts of phase and group velocities. We also introduce flow in rapidly rotating systems, like Taylor columns and Eckman layers. Finally, we briefly introduce modern experimental techniques used in fluid dynamics, like laser-induced fluorescence, hot-wires, Particle Image Velocimetry. |

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| **Course Description from Program Guide** | Fundamentals of fluid mechanics. Microscopic and macroscopic properties of liquids and gases; the continuum hypothesis; review of thermodynamics; general equations of motion; kinematics; stresses; constitutive relations; vorticity, circulation; Bernoullis equation; potential flow; thin-airfoil theory; surface gravity waves; buoyancy- driven flows; rotating flows; viscous creeping flow; viscous boundary layers; introduction to stability and turbulence; quasi one-dimensional compressible flow; shock waves; unsteady compressible flow; acoustics. |
| **Goals and Objectives** | Prepare students for advanced understanding of the topic, to prepare them for performing research. |
| **Required Knowledge** | Basic concepts of mechanics. Newton's laws of motion. First course on hydrodynamics. Differential calculus. |
| **Reference Texts** | Fluid Mechanics. by P.K. Kundu & I. M. Cohen. AP<br>Incompressible flows by R.L. Panton, Wiley |
| **Method of evaluation** | **10.00**% - Attendance and Participation<br>**35.00**% - Midterm exam<br>**15.00**% - Homework /Assignments<br>**40.00**% - Final exam |
| **Nature of the assignments** | Weekly homework assignments. |
| **Course Policies** | Lecture attendence is mandatory.<br>Midterm and Final exams are closed book/ closed notes. |
| **Additional Information** | |

| Tentative Course Schedule<br>*(Time, topic/emphasis & resources)* | | |
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| **Week** | **Lectures** | **Topic** |
| 1 | Sun 08/26/2018 | Basics: Continuum hypothesis; Surface tension |
| 1 | Wed 08/29/2018 | Vector calculus and index notation |
| 2 | Sun 09/02/2018 | Material derivative; Kinematics; Lagrangian vs Eulerian |
| 2 | Wed 09/05/2018 | Governing Eq.: Reynolds Transport Theorem; Continuity; Euler equations; Constitutive equation |
| 3 | Sun 09/09/2018 | Navier-Stokes equation; Boundary conditions |
| 3 | Wed 09/12/2018 | Dimensional analysis |
| 4 | Sun 09/16/2018 | Self-similar solutions |
| 4 | Wed 09/19/2018 | Exact Solutions of N.-S.; Unidirectional flow |
| 5 | Sun 09/23/2018 | Stagnation point flow |
| 5 | Wed 09/26/2018 | Stokes firts and second problems |
| 6 | Sun 09/30/2018 | Flow in converging or diverging channel |
| 6 | Wed 10/03/2018 | Stokes streamfunction for axisymmetric flow |
| 7 | Sun 10/07/2018 | Bernoulli equation for unsteady flow |
| 7 | Wed 10/10/2018 | Potential Flow; Kelvin's circulation theorem |
| 8 | Sun 10/14/2018 | Basic potential solutions, doublet |
| 8 | Wed 10/17/2018 | Review |
| 9 | Sun 10/21/2018 | Midterm exam |
| 9 | Wed 10/24/2018 | Potential flow: Complex potential - Flow in a sector |
| 10 | Sun 10/28/2018 | Potential flow: Airfoil theory - Sphere impact - Virtual mass - Blasius theorem |
| 10 | Wed 10/31/2018 | Potential flow: Conformal mapping - Schwarz Christoffel transformation |
| 11 | Sun 11/04/2018 | Potential flow: Bubble accelerations - Boundary integral methods |
| 11 | Wed 11/07/2018 | Vortex dynamics: Vorticity equation - Circulation |
| 12 | Sun 11/11/2018 | Vortex dynamics: Vortex rings - Biot Savart law |
| 12 | Wed 11/14/2018 | Vortex dynamics: Hill's spherical vortex - Vorticity generation at a free surface - Helicity |
| 13 | Sun 11/18/2018 | Surface waves: Gravity waves |
| 13 | Wed 11/21/2018 | Surface waves: Capillary waves - Group velocity - Waves on bubbles |
| 14 | Sun 11/25/2018 | Rotating flows: Taylor columns - Eckman layers |
| 14 | Wed 11/28/2018 | Experimental techniques: hot wires - high speed imaging |
| 15 | Sun 12/02/2018 | Experimental techniques: Particle Image Velocimetry - Laser Induced Fluorescence |
| 15 | Wed 12/05/2018 | Review |
| 16 | Sun 12/09/2018 | Final Exam |

### Note

The instructor reserves the right to make changes to this syllabus as necessary.