LECTURE #1

Course Policies

Course Introduction

Relation to ES201, 203, 204, 205

Thermodynamics vs Fluid mechanics vs Heat Transfer

Def^n of a Fluid (vs. a Solid)

shear vs normal stress

Flow Classification

Internal vs External

Single-Phase vs Two-Phase

Compressible vs Incompressible

No slip condition

~~Vapor Pressure~~

"Field"

Continuity Eqn

$$\boxed{\frac{\partial \rho}{\partial t} = -\frac{\partial}{\partial x}(\rho V_x) - \frac{\partial}{\partial y}(\rho V_y) - \frac{\partial}{\partial z}(\rho V_z)}$$

SS

Incompressible

Thermodynamics

science of energy

Heat Transfer

study of energy transfer
due to temperature differences

Fluid Mechanics

science that deals with
the behavior of fluids at rest or
in motion AND their interactions
with other bodies

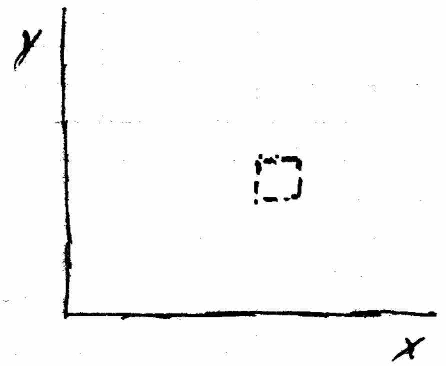
Fluid — a substance that deforms
continuously under application of
a shear stress.

Classification

No-slip condition

~~Vapor Pressure~~

Conservation of mass for a differential open system



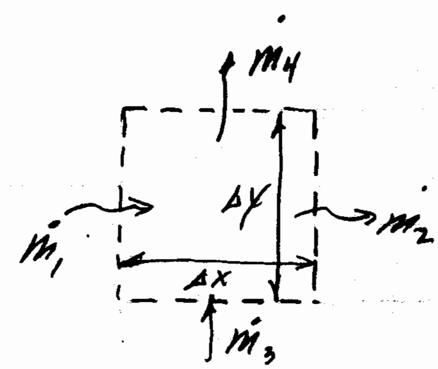
Scalar Field

$\rho = \rho(x,y,t)$

$V_x = V_x(x,y,t)$

$V_y = V_y(x,y,t)$

$\vec{V} = V_x \hat{i} + V_y \hat{j} \longrightarrow \vec{V} = \vec{V}_{(x,y,t)}$ Vector Field



$$\frac{dm_{sys}}{dt} = (\dot{m}_1 - \dot{m}_2) + (\dot{m}_3 - \dot{m}_4)$$

~~depth~~ into paper

$$m_{sys} = \int_{\forall} \rho \, d\forall = \tilde{\rho}(\Delta x \Delta y) w$$

Average value in

$x \rightarrow x + \Delta x$

$y \rightarrow y + \Delta y$

$\dot{m}_1 = \widetilde{(\rho V_x)}_1 (\Delta y) w \qquad \dot{m}_2 = \widetilde{(\rho V_x)}_2 \, w \Delta y$

$\dot{m}_3 = \widetilde{(\rho V_y)}_3 \, w \Delta x \qquad \dot{m}_4 = \widetilde{(\rho V_y)}_4 \, w \Delta x$

$$m_{sys} = \int \rho \, d\forall = \tilde{\rho} \Delta \forall$$
$$= \tilde{\rho} \, w \Delta x \Delta y$$

$$w \Delta x \Delta y \frac{\partial \tilde{\rho}}{\partial t} = w \left[\widetilde{(\rho V_x)}_1 - \widetilde{(\rho V_x)}_2 \right] \Delta y$$
$$+ w \left[\widetilde{(\rho V_y)}_3 - \widetilde{(\rho V_y)}_4 \right] \Delta x$$

$$\frac{\partial}{\partial t} \tilde{\rho} = - \frac{\widetilde{(\rho V_x)}_2 - \widetilde{(\rho V_x)}_1}{\Delta x} - \frac{\widetilde{(\rho V_y)}_4 - \widetilde{(\rho V_y)}_3}{\Delta y}$$

Limit as $\Delta x, \Delta y \to 0$
$$\boxed{\frac{\partial \rho}{\partial t} = - \frac{\partial}{\partial x}(\rho V_x) - \frac{\partial}{\partial y}(\rho V_y)}$$

Steady $\quad \partial \rho / \partial t = 0$

Incompressible
$$\boxed{\frac{\partial V_x}{\partial x} + \frac{\partial V_y}{\partial y} = 0}$$

Vector Notation

$$\vec{\nabla} \equiv \hat{i}\frac{\partial}{\partial x} + \hat{j}\frac{\partial}{\partial y} + \hat{k}\frac{\partial}{\partial z}$$

"Operator Del"

$$\therefore \quad \frac{\partial \rho}{\partial t} + \underbrace{\vec{\nabla}\cdot(\rho\vec{V})}_{\text{Divergence of } \rho\vec{V}} = 0$$

"Net out flow"

In 3-dimensions,

$$\underbrace{\frac{\partial \rho}{\partial t}}_{\text{Time rate of change of mass per unit volume at a point [Accumulation]}} = -\underbrace{\left[\frac{\partial(\rho V_x)}{\partial x} + \frac{\partial(\rho V_y)}{\partial y} + \frac{\partial(\rho V_z)}{\partial y}\right]}_{\text{Net mass flow rate into a point per unit volume [Transport]}}$$

<table>
<tr><th>Lecture #</th><th>Lecture objectives</th><th>Assignment</th></tr>
<tr><td>1</td><td>Connection between ES 201, 202, and 204
What is "fluid mechanics"? Highlight some applications.
What is "thermodynamics"? Highlight some applications.
Definition of a fluid
response of a fluid to a stress
contrast that with the response of solid
Concept of a field variable
Derive the continuity equation in Cartesian coordinate using the Eulerian approach
Stress the interpretation of individual terms: inflow, outflow, zero generation
Definition of an incompressible fluid</td><td>Watch the video titled "Flow Visualization"

Problems on checking if a given flow is incompressible</td></tr>
<tr><td>2</td><td>Visualization of fluid flow
Concept of streakline, streamline, path line using Multi-Media Fluid Mechanics CD as a teaching tool
Types of kinematic motion of a fluid elements
translation
expansion / compression
rotation (definition of vorticity)
angular deformation
Stream function</td><td>Watch the video titled "Deformation of Continuous Media"

Problems on checking if a given flow is irrotational, sketching of streamlines</td></tr>
<tr><td>3</td><td>Derive the Euler equation in Cartesian coordinate using the Eulerian approach
Definition of viscosity
Stress-strain-rate relationship of a Newtonian fluid
Introduce the Navier-Stokes equation for an incompressible fluid by incorporating viscous forces to the Euler equation
Stress the interpretation of individual terms: inflow/outflow mass transfer, force transfer (surface force in normal and tangential directions; body force), zero generation</td><td>Problem on a 2D internal flow problem (Couette or Poiseuille) high-lighting the effect of viscosity

Problem comparing a 1D and 2D analysis – momentum correction (deficient) factor and its connection to the viscous effects</td></tr>
</table>