M E 320 – Fluid Flow

Today, we will:

- Introduce the course and instructor: **John M. Cimbala, 863-2739, jmc6@psu.edu**
- Briefly go over the course website at **www.mne.psu.edu/me320-2**
- Introduce fluid mechanics – What is a fluid? What is mechanics?
- Begin a discussion about classification of fluid flows

I. Intro

A. What is Fluid Mechanics?

Fluid – liquid or gas

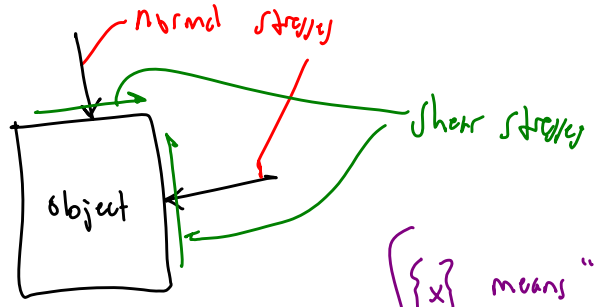
If there are no free surfaces, air & water behave similarly

exception: at high speeds, air becomes compressible

Fluid ≡ A substance that deforms continuously under the application of a shear stress.

Free Body Diagram

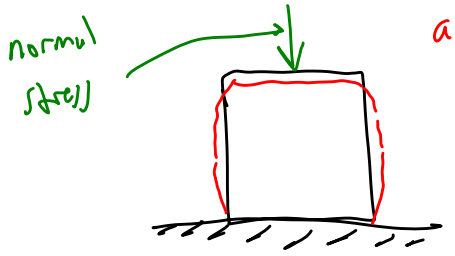
$$\{\text{Stress}\} = \left\{\frac{\text{Force}}{\text{Area}}\right\}$$



$\{x\}$ means "the dimensions of x"

Apply a normal stress:

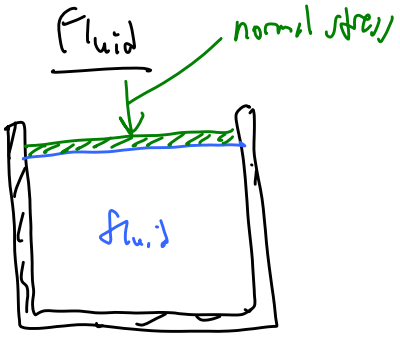
Solid



A solid at rest can resist a normal stress

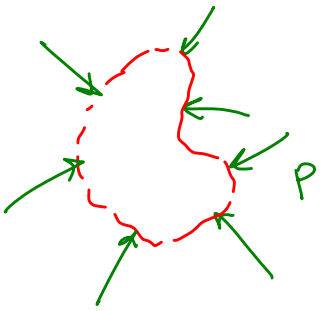
A fluid at rest can resist a normal stress

Fluid



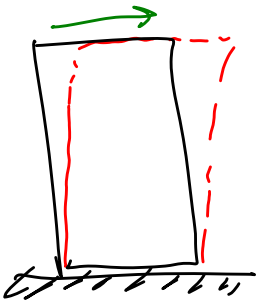
In fluids, the normal stress is called pressure

Pressure always acts inward & normal



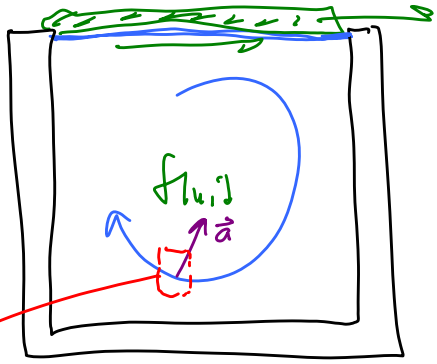
Apply a shear stress

SOLID



The solid at rest can resist a shear stress

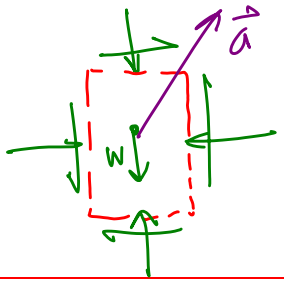
FLUID



The fluid cannot stay at rest and resist the shear stress — it will deform

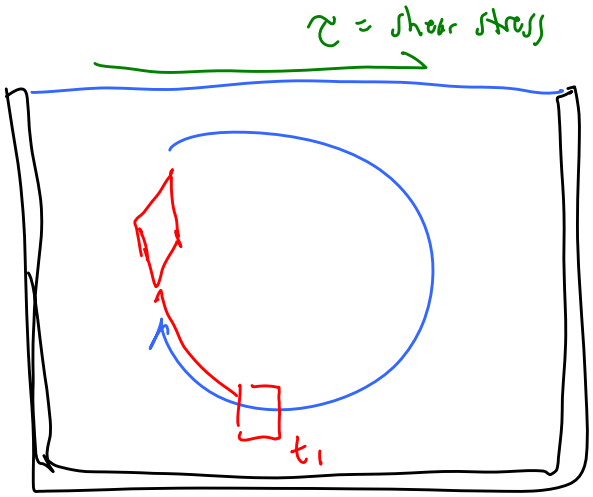
★ A fluid at rest cannot resist a shear stress (it will move)

FBD of this little chunk of fluid:
- pressure (normal stress)
- shear stress
- gravity force



$$\sum \vec{F} = m\vec{a}$$

The fluid particle also moves & distorts



2. Mechanics → The application of the laws of force & motion

Two branches: Statics (E. Mech 211) $\sum \vec{F} = 0$

Dynamics (" 212) $\sum \vec{F} = m\vec{a}$

We will discuss:

1) fluid statics → hydrostatics = fluid at rest $\sum \vec{F} = 0$

2) fluid dynamics → fluids in motion $\sum \vec{F} = m\vec{a}$

B. Classification of Fluid Flows

1. Viscous vs. Inviscid regions of the flow

All fluids are viscous

Inviscid does not mean zero viscosity

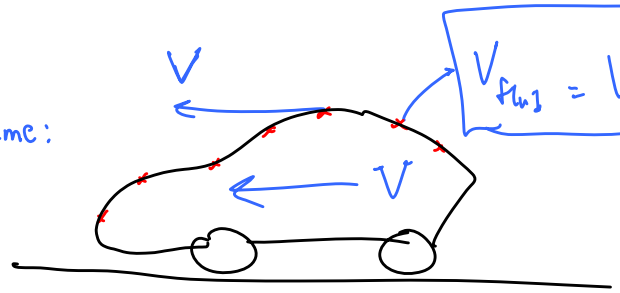
Inviscid ≡ regions in the flow where viscous effects are negligible

No-slip condition

$$\vec{V}_{fluid} = \vec{V}_{wall}$$

for a fluid in contact with a wall

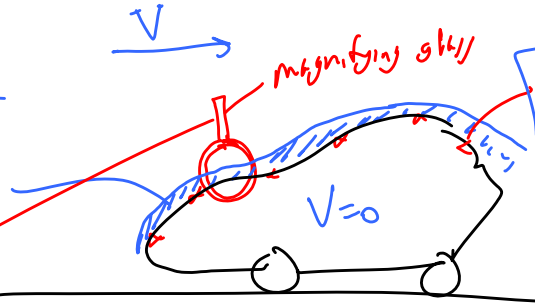
Stationary reference frame: (car moving)



$V_{fluid} = V_{car}$

the air just above the car surface moves at same speed as the car

Moving with the car:



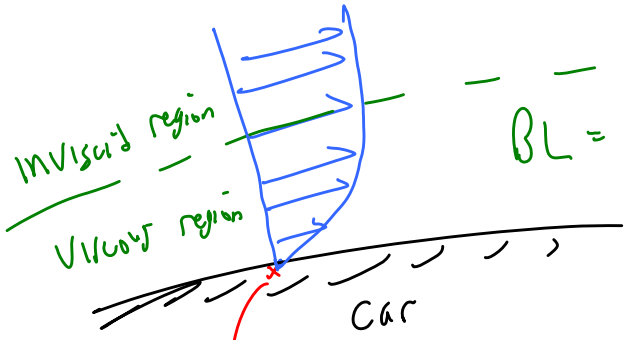
$V_{fluid} = 0$

(car is still, air moving around it)

Boundary Layer

Thin region in the flow where viscous effects are important (a viscous region)

Outside of the BL, the flow is called "inviscid region of flow"



BL = Boundary Layer

$V=0$ @ the wall

Mach #

$$Ma = \frac{V}{c}$$

2. Internal vs External

3. Compressible vs Incompressible

In a gas, ρ changes by $\simeq 5\%$ when $Ma \leq 0.3$

↓

can consider the flow incompressible