Today, we will:

- Continue talking about classifications of fluid flow
- Discuss dimensions, units, unit conversions, and significant digits
- Begin Chapter 2 – Properties of Fluids

B. Classification of Fluid Flows (continued)
1. Viscous vs. inviscid regions of flow
2. Internal vs. external flow
3. Compressible vs. incompressible flow
4. Laminar vs. turbulent flow

From previous lecture

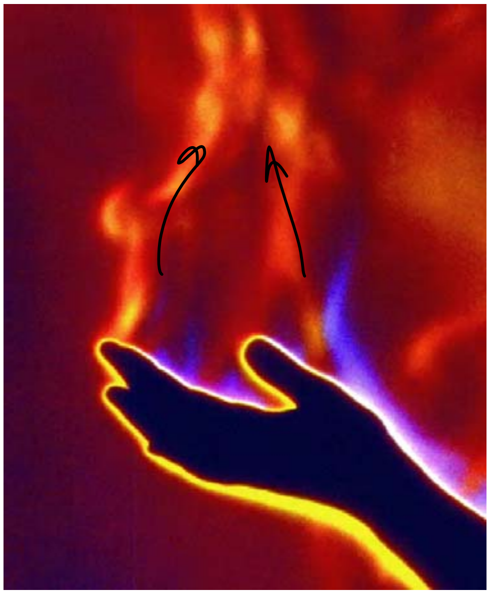
Laminar flow

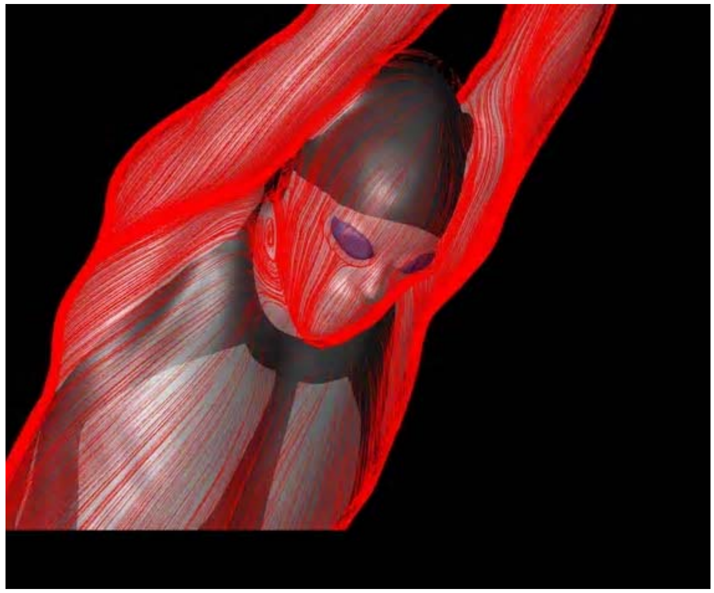
Laminar flow
Smooth, orderly
typically steady, but can be unsteady

Turbulent flow

Turbulent flow
chaotic, unsteady
can be steady in the mean
turbulent eddies, lots of mixing, random motion

5. Natural vs. forced flow



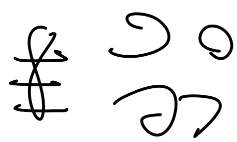


Natural (unforced) **Forced**

6. Steady vs. unsteady

- not changing with time
- can be periodic, & ∴ unsteady, but it can be steady in the mean

e.g. fan

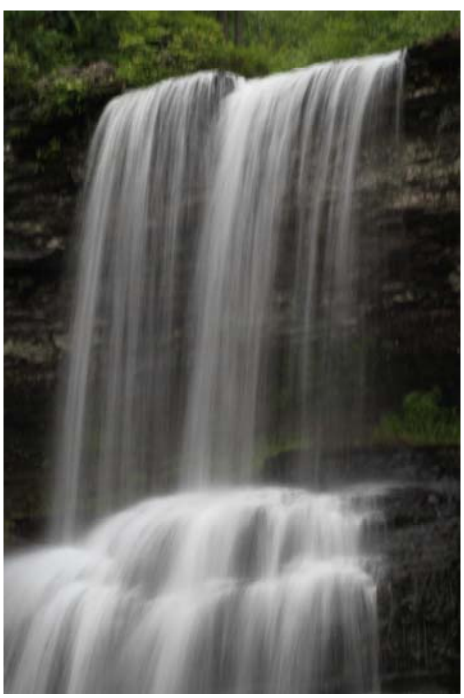


eddies - unsteady

time avg. velocity profile is steady

We call this "Stationary flow"

(steady in the mean)

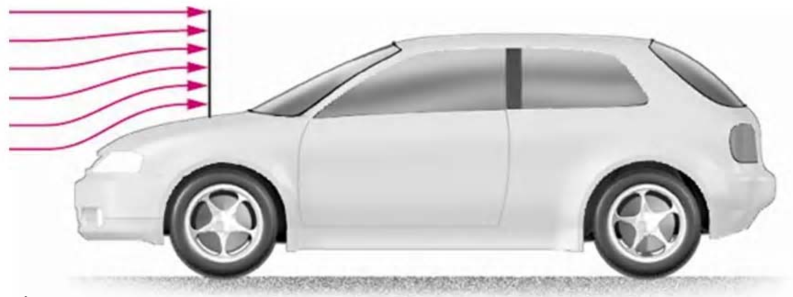


Steady in the mean **Unsteady**

long time exposure short time exposure

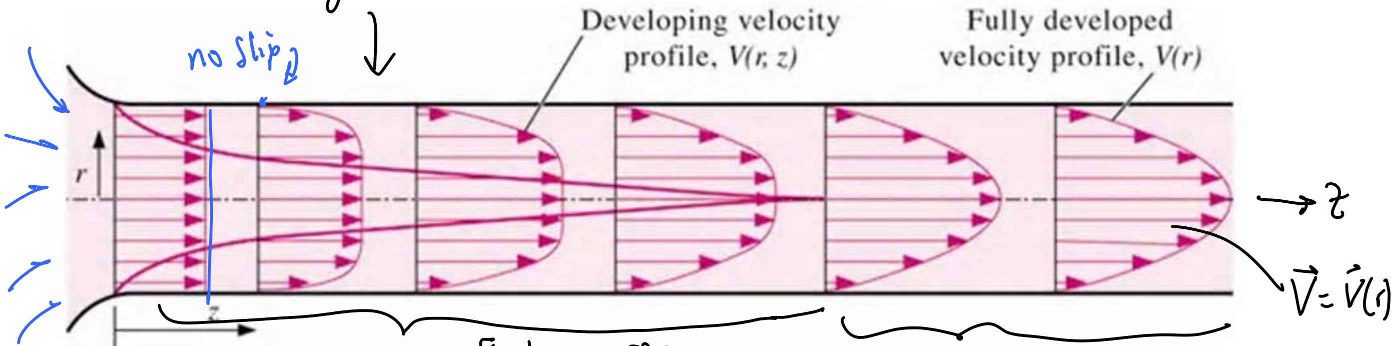
7. One-, two-, or three-dimensional

3-D → $\vec{V} = \vec{V}(x, y, z)$
or $\vec{V}(r, \theta, z)$
[& also can be a fnc. of time]



2-D → $\vec{V} = \vec{V}(x, y)$ or $\vec{V}(y, z)$ ... (depends on 2 spatial coordinates)

E.g., pipe flow in the entrance region



Entrance region

Fully developed region

$\vec{V} = \vec{V}(r, z)$ = 2-D (axisymmetric)
↙ does not depend on θ

Fully developed region → Pressure decreases with z

1-D → $\vec{V}$ = fnc. of only one variable

In fully developed region, $\vec{V} = \vec{V}(r)$ → 1-D

For pressure, $P = P(z)$ in the fully developed region

C. Dimensions, Units, and Significant Digits

1. Dimension = characterization of a physical variable w/o a number e.g., length
2. Unit = A way to assign a number to a dimension. e.g., meter
3. Unit conversions, unity conversion ratios

Use unity conversion ratios → express the conversion as a ratio. → no dimensions ∴ unity of 1

e.g. $\left(\frac{12\text{ in}}{\text{ft}}\right)$, $\left(\frac{60\text{ s}}{\text{min}}\right)$, $\left(\frac{1\text{ kg}}{2.205\text{ lbm}}\right)$, etc.

unity conv. factors = 1

∴ We can put them into equations where needed.

Example: Unit conversions

Given: The mass of an object is m = 2.00 kg.

To do: How much does this mass weigh on earth in units of lbf?

Solution:

Newton's 2nd law: $\vec{F} = m\vec{a}$ or $\vec{W} = m\vec{g}$

Since $\vec{W}$ & $\vec{g}$ are both downward, $W = mg$

$$W = mg = (2.00\text{ kg})\left(9.81\frac{\text{m}}{\text{s}^2}\right)\left(\frac{\text{N}}{\text{kg}\cdot\text{m/s}^2}\right)\left(\frac{1\text{ lbf}}{4.44822\text{ N}}\right) = 4.410753065\text{ lbf}$$

unity conversion ratios

Too many digits! → false implication of precision

$$\cong 4.41\text{ lbf}$$

4. Significant digits

- When multiplying or dividing, the answer should have the same # of sig. digits as the variable with the smallest # of sig. digits ☆

- For addition or subtraction
  - line up decimal pts
  - choose the appropriate column for sig. digits

e.g. what is 3.02 + 0.00803? →

$$\begin{array}{r} 3.02 \\ +\ 0.00803 \\ \hline 3.02803 \end{array}$$

Ans → 3.03

Keep all digits in intermediate calculations to avoid round-off error ☆

D. Fluid Properties (Chapter 2)

1. Kinematic properties → related to fluid motion

   e.g., $\vec{V}$, $\vec{a}$ (see in Ch. 4)

2. Thermodynamic properties

   T temperature
   P pressure
   v specific volume
   u internal energy

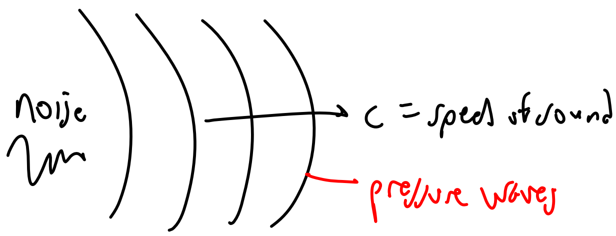
   in thermo we like v; in fluids we like to use ρ = density

   $$\rho = \frac{1}{v}$$ ☆

3. Other (miscellaneous) properties

   a. speed of sound, c

   $$\{\rho\} = \left\{\frac{m}{L^3}\right\}$$



In general $$c = \sqrt{\left(\frac{\partial P}{\partial \rho}\right)_s}$$

In an ideal gas, $$c = \sqrt{kRT}$$

$k = c_p/c_v$, R = specific gas constant

$$R = \frac{R_u}{M}$$

Mach number → $$Ma = \frac{V}{c}$$

if $Ma < 1$ subsonic
if $Ma > 1$ supersonic

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b. vapor pressure P_v

P_v = same as P_{sat} in thermo

recall the "steam tables"

e.g. @ $T = 20°C$, $P_{sat} = P_v = 2.339$ kPa (water)

At $T = 20°C$, water will boil when P drops below 2.339 kPa

@ $T = 100°C$, $P_{sat} = 101.3$ kPa (water)

Water boils at 100°C when $P = 101.3$ kPa (standard atmosphere)

b. vapor pressure, P_v (cont).

In fluid mechanics, P_v is important because we can have local "boiling" in regions of low pressure.

Cavitation → when the liquid vaporizes due to low pressure

In general as $V \uparrow$ $P \downarrow$

Cavitation is a concern in regions of high V, & low P

"Cavitation bubbles" will form when the local $P < P_v$ ⊛

Why is cavitation a concern?

1) noise
2) causes damage to surfaces (pitting) (see pictures on website – pdf tab)

Also see the supercavitating video clip on the website – (videos tab)

They purposely have cavitation on a torpedo body so that the drag is much reduced. Very cool.