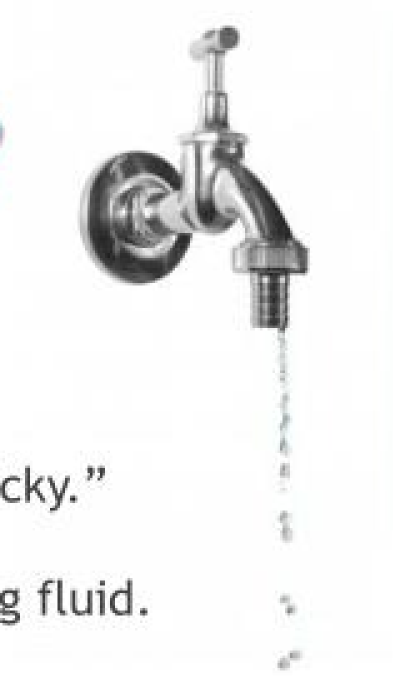
# VISCOSITY

BRANZUELA | LANGOMEZ | PESTANO | VELEZ

# What is Viscosity?



- "viscosity" is derived from the

  Latin word "viscum", meaning "anything sticky."
- It describes the internal friction of a moving fluid.
- A fluid with large viscosity resists motion
- A fluid with low viscosity flows
- Viscosity is a measure of the resistance of a fluid which is being deformed by either shear stress or tensile stress. In everyday terms (and for fluids only), viscosity is "thickness" or "internal friction".

# A simulation of substances with different viscosities

- The substance above has lower viscosity than the substance below

Honey has a higher viscosity than water.

# According to Newton..

$$\eta = \frac{\tau}{\dot{\gamma}} = \frac{shearstress}{shearrate}$$

*"the resistance which arises from the lack of slipperiness of the parts of a fluid, other things being equal, is proportional to the velocity with which the parts of the liquid are separated from each other"*

- represented by the Greek letter η (eta)

- SHEAR STRESS
  - the external force acting on an object or surface parallel to the slope or plane in which it lies; the stress tending to produce shear.

- TENSILE STRESS
  - *A force that attempts to pull apart or stretch a material.*

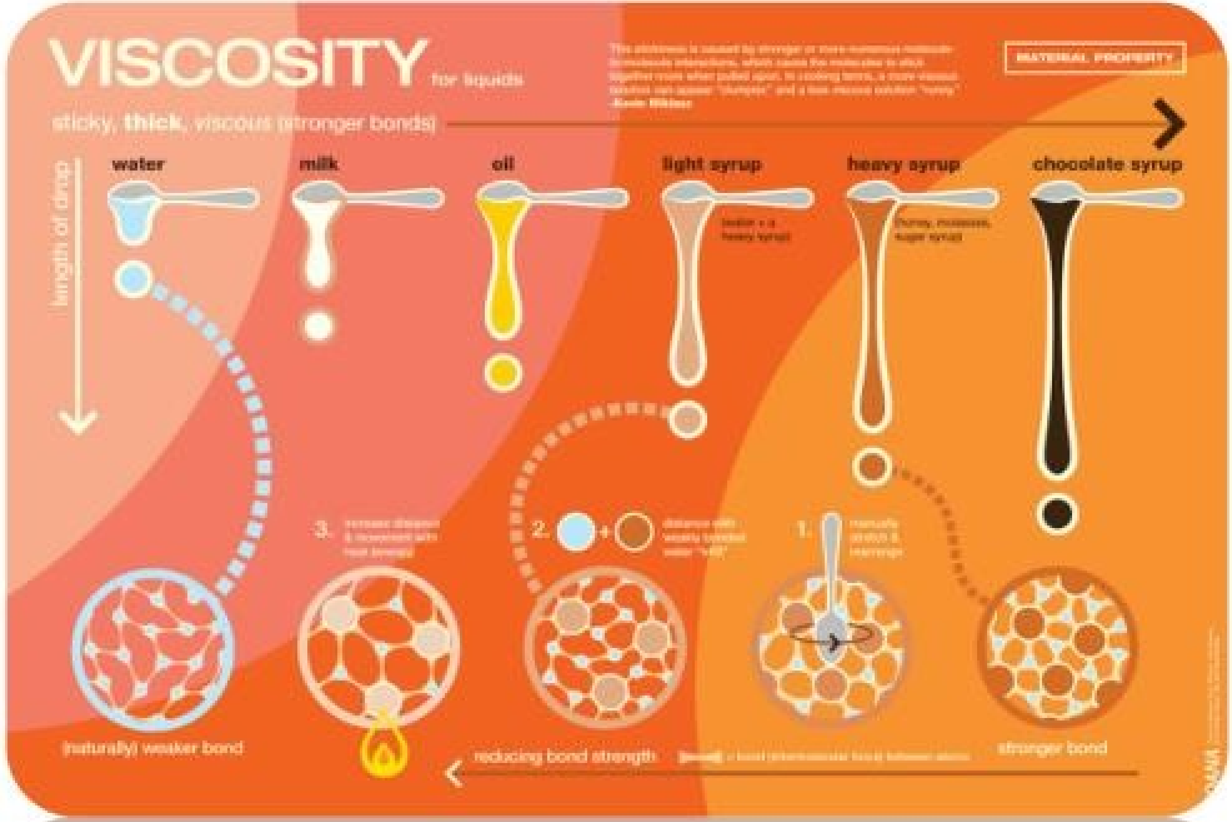
$$\eta = \frac{\tau}{\dot{\gamma}} = \frac{shearstress}{shearrate}$$

- FLOW RATE
  - or "how fast a fluid flows"
  - is a qualitative way to measure the viscosity of a fluid.

## **Rheology** /riːˈɒlədʒi/

- is the study of the flow of matter, primarily in the liquid state

- It applies to substances which have a complex microstructure, such as muds, sludges, suspensions, polymers and other glass formers (*e.g.*,silicates), as well as many foods and additives, bodily fluids (*e.g.*, blood) and other biological materials or other materials which belong to the class of soft matter.


VISCOSITY for liquids
MATERIAL PROPERTY
sticky, thick, viscous (stronger bonds)
length of drop
water
milk
oil
light syrup
heavy syrup
chocolate syrup
3.
2.
1.
(naturally) weaker bond
reducing bond strength
stronger bond

# Factors that Affect Viscosity

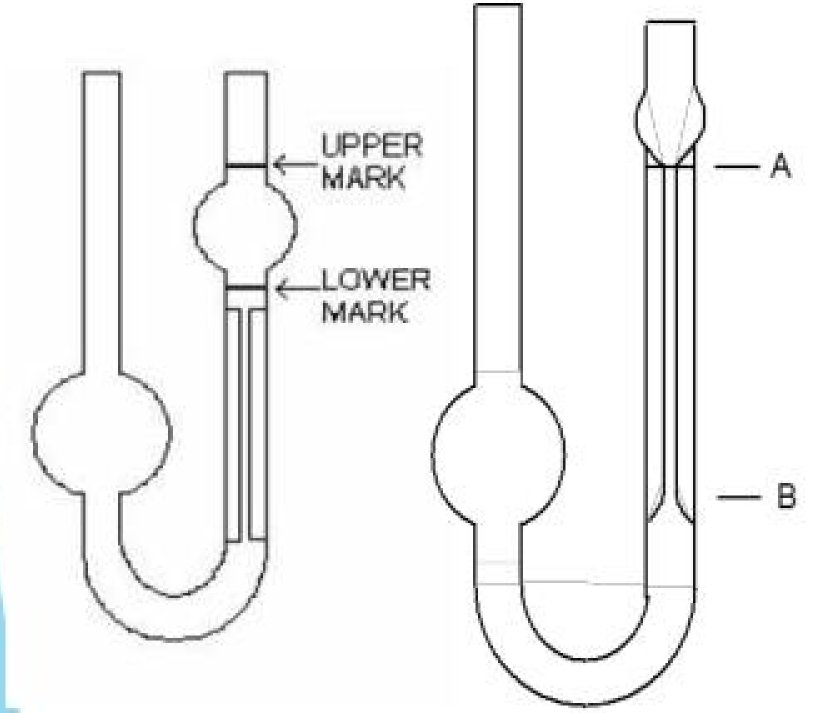
| | | |
|---|---|---|
| Speed of Particles | As speed increases, viscosity decreases | As speed decreases, viscosity increases |
| Attraction | As attraction increase, viscosity increases | As attraction decreases, viscosity decreases |
| Space Between Particles | As the space increases, viscosity decreases | As the space decreases, viscosity increases |
| **Amount of Energy (heat)** | **As the temperature increases, viscosity decreases** | **As the temperature decreases, viscosity increases** |

Example:

- Volcano Lava

# EQUIPMENTS USED FOR VISCOSITY

## *VISCOMETER*




Time for a fluid to fall from point A to B given by:

$$\frac{\eta}{\rho} = k\ t$$

## *RHEOMETER*

# WHY MEASURE VISCOSITY

- Viscosity can change dramatically with temperature, it is important to understand what will happen to lubricants at high temperatures and pressures or low temperatures. Failure to do so could result in design errors.

- Viscosity is important in many commercial applications, such as consumer products like shampoo, and viscometers are used extensively in quality control.

# Turbulence

- ✓ irregular, chaotic flow of fluid
- ✓ changes continuously with time
- ✓ has no stead-state pattern.

- **Turbulent Flow**

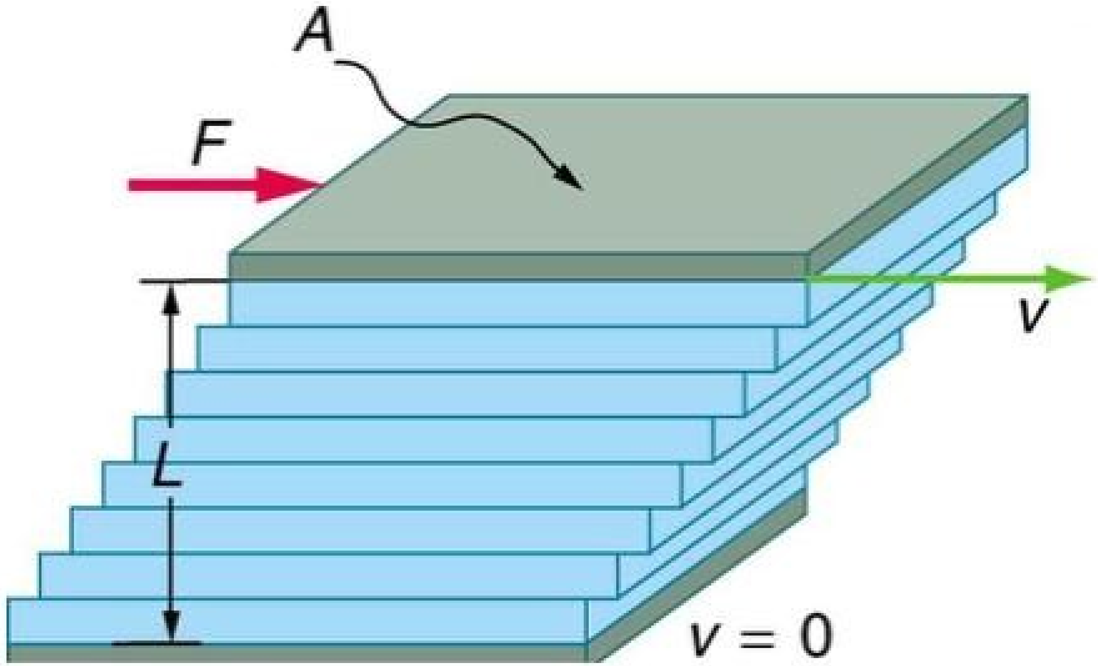
  - is a disorderly flow of fluid. Small packets of fluid moves towards all directions and all angles to normal line of flow.

  - *Fluid flow is dependent on it's viscosity.*

# #THROWBACK

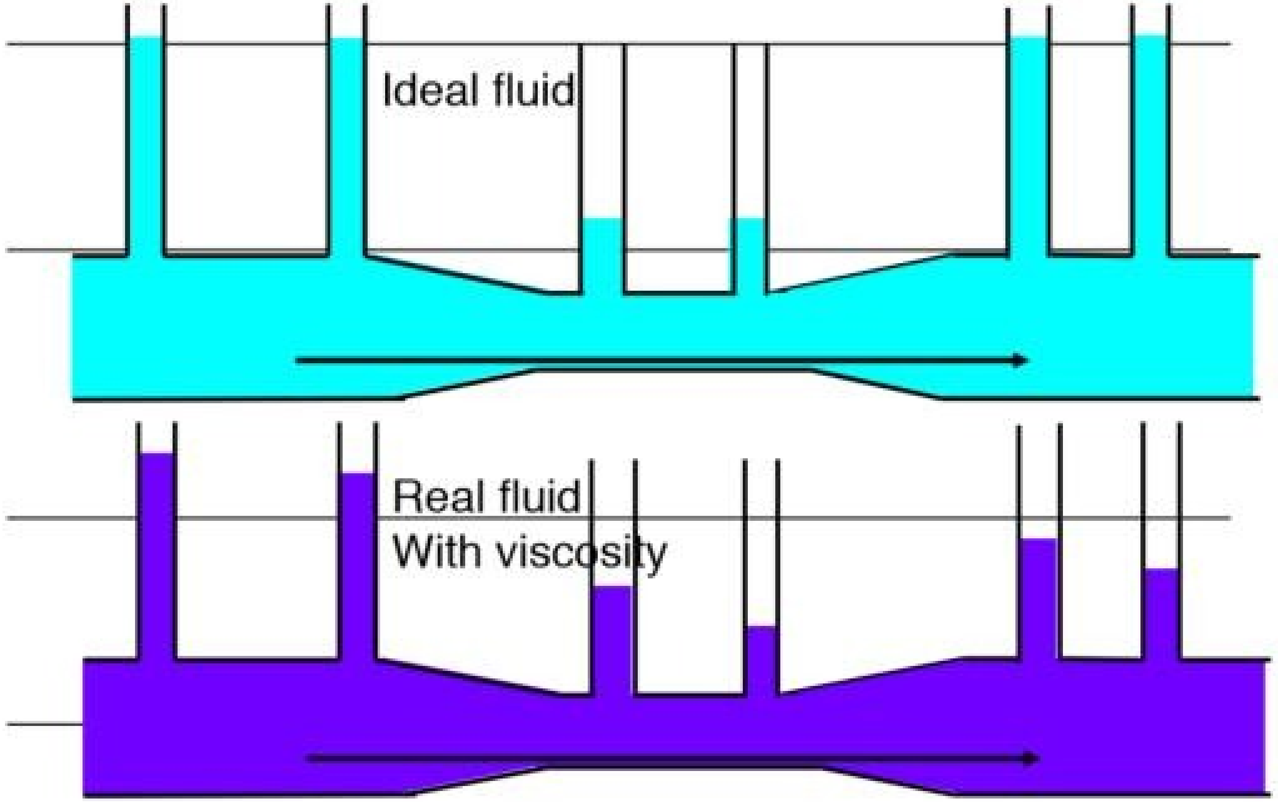
| IDEAL FLUID | REAL FLUID |
|---|---|
| Incompressible- density is constant | Compressible- density is NOT constant |
| Irrotational- the fluid is smooth, no turbulence | |
| Nonviscous- has NO internal friction | Viscous- has internal friction |

- When real fluids flow they have a certain internal friction called viscosity. It exists in both liquids and gases and is essentially a **frictional force** between different layers of fluid as they move past one another.
- In liquids the viscosity is due to the cohesive forces between the molecules while in gases the viscosity is due to collisions between the molecules.




- F for FORCE
- V for VELOCITY
- A for AREA
- L for distance

A force $F$ is required to keep the top plate from moving at a constant velocity $v$, and experiments have shown that this force depends on four factors.




•In a real fluid the pressure decreases along the pipe.
•Viscous fluids have frictional forces which dissipate energy through heating.

# Coefficient of Viscosity

The constant of proportionality for the fluid is called the

coefficient of viscosity

**$F = \eta A v / L$**

which gives us a working definition of fluid **viscosity *η*.**
Solving for *η* gives

$\eta = FLvA$

The SI unit of viscosity is N·m/[(m/s)m2]=(**N/m2)s or**

$$(F/A) = \eta\ (v / L)$$

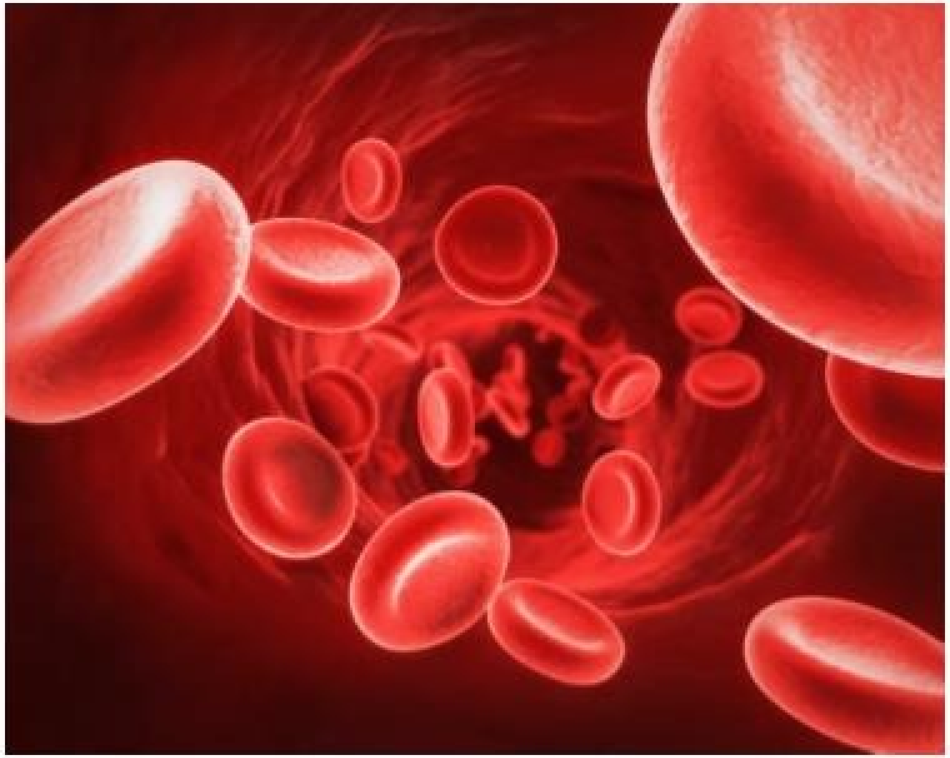
$$\eta = (F / A)(L / v)$$

coefficient of viscosity $\eta$ (Greek letter eta).

The greater the coefficient of viscosity $\eta$, the greater the force required to move the plate at a velocity *v*.

This relationship does not hold for all fluids. Viscous fluids that obey this equation are called **Newtonian fluids** and $\eta$ = constant independent of the speed of flow.

When $\eta$ does depend upon the velocity of flow the fluids are called **non-Newtonian or rheological fluids.**

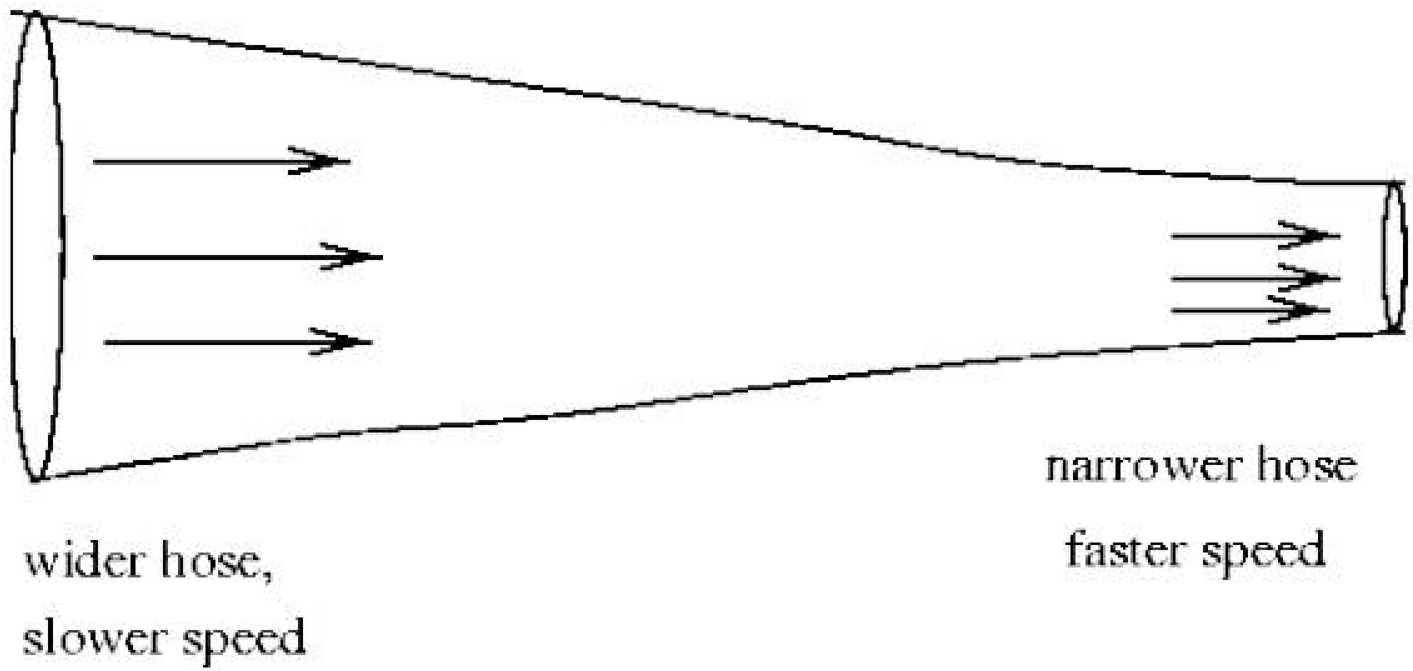


# Equation of Continuity

- The equation of continuity works under the assumption that the flow in will equal the flow out.
- The ``continuity equation'' is a direct consequence of the rather trivial fact that what goes into the hose must come out. The volume of water flowing through the hose per unit time

$$A_1 v_1 = A_2 v_2$$

# Continuity Equation



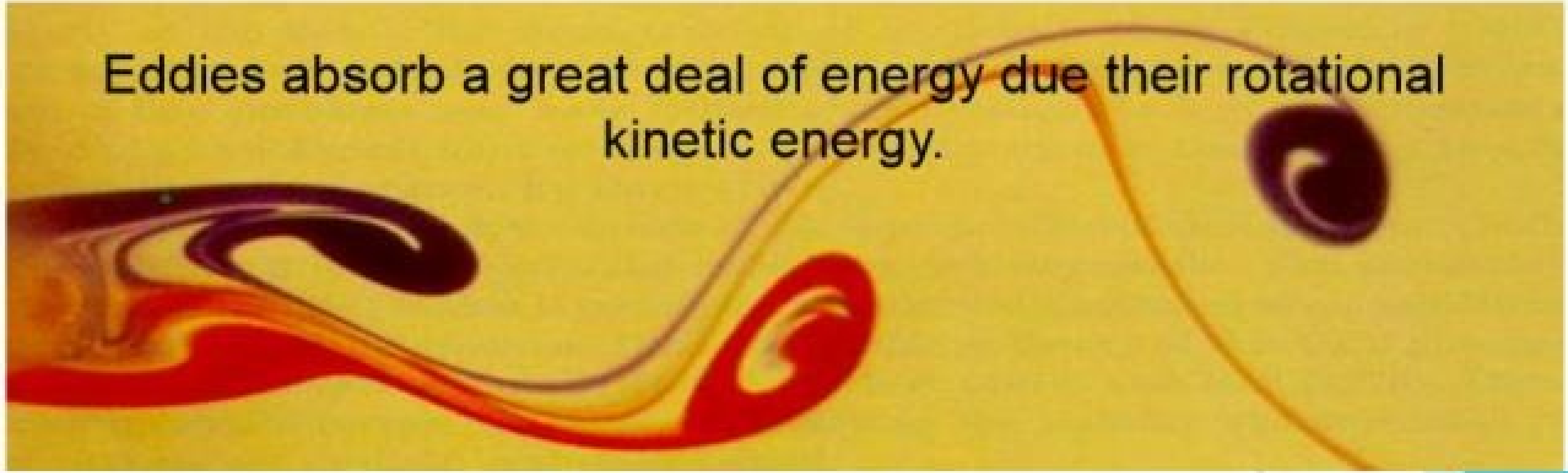

You can easily verify that (area)x(velocity) has units $m^3/t$ which is correct for volume per unit time.

$$A_1 v_1 = A_2 v_2$$

# Turbulence

Until now we have discussed laminar flow. When the motion becomes too violent, eddies and vortices occur. We call this turbulent motion.

The pattern of flow is no longer smooth and stable but becomes irregular and chaotic. A complex flow pattern changes continuously with time. The velocity of the particles at each given point varies chaotically with time.



# Turbulence

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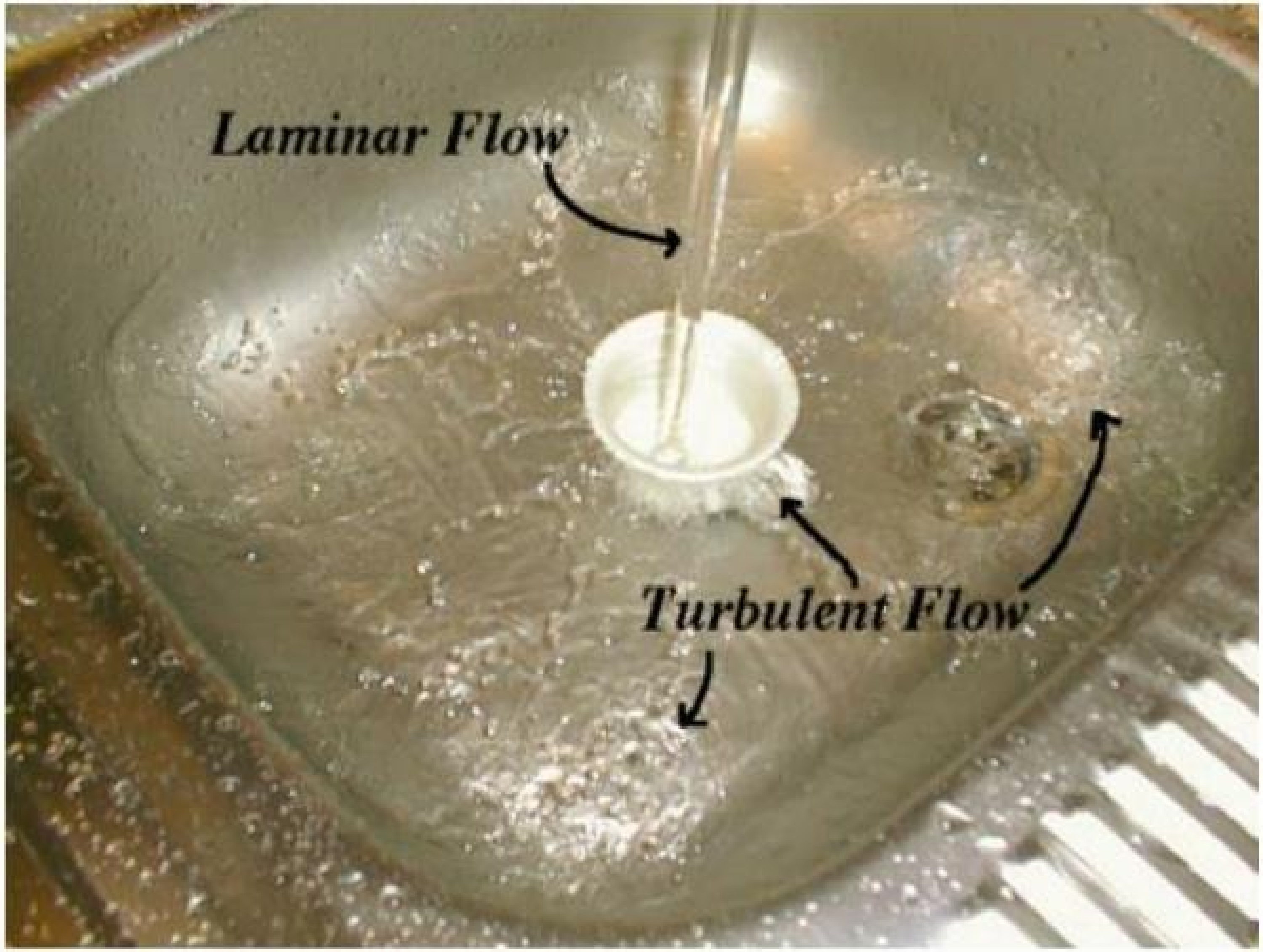
- When the flow becomes turbulent there is a decrease in the volume flow rate.

•When a fluid flows around an object the shape of the object is a very important parameter in determining the type of flow.

•Thicker liquids like honey (or Kahlua in milk) do not get turbulent as easily as thin ones like water (or whiskey) .


Laminar Flow
Turbulent Flow

# Poiseuille’s Equation

# Poiseuille's Equation

- In fluid dynamics, the Hagen–Poiseuille equation, also known as Poiseuille law or Poiseuille equation,
- is a physical law that gives the pressure drop in a fluid flowing through a long cylindrical pipe. It can be applied to air flow in lung alveoli, for the flow through a drinking straw or through a hypodermic needle.
- It was experimentally derived independently by Gotthilf Heinrich Ludwig Hagen in 1839 and Jean Léonard Marie Poiseuille in 1838, and published by Poiseuille in 1840 and 1846.

- Poiseuille’s equation only holds under two conditions:
  - Incompressible fluid (density is constant)
  - Laminar fluid flow (steady fluid flow)

- Poiseuille's law only applies to newtonian fluids . Non-newtonian liquids do not obey Poiseuille's law because their viscosities are velocity dependent.

- Poiseuille's law is found to be in reasonable agreement with experiment for uniform liquids (called Newtonian fluids) in cases where there is no appreciable turbulence.

# Poiseuille's Equation (Flow in tubes)

- What causes flow?
  - Difference in pressure causes flow, Flow rate (Q) is in the direction from high to low pressure.

- This relationship can be stated as:

$$Q = \frac{P_2 - P_1}{R}$$

- Resistance (R) includes everything, except pressure
- This resistance depends linearly upon the viscosity and the length

$$R = \frac{8\eta l}{\pi r^4}$$

- This equation is [obscured] :ance, derived an attempt to understand the [obscured] nt fluid.

- So, both equations taken together an $Q = \frac{P_2 - P_1}{R}$
- We $R = \frac{8\eta l}{\pi r^4}$ ing expression for flow rate:

or $Q = \frac{\pi r^4 (P1 - P2)}{8\eta l}$

$$Q = \frac{(P_2 - P_1)\pi r^4}{8\eta l}$$

# Applications:

- Poiseuille's equation can also be applied to the blood flow.
- Applied in the calculation of flow of blood through the vessels or heart (rheology of cardiovascular system) and the flow of air and expiratory gas through the airways
- Blood flowing in our blood vessels.
- It states that the rate of flow depends on the radius of the tube and when it gets smaller the pressure must increase to keep the same flow rate. Here the body needs a certain amount of oxygen from the blood, so when the artery gets clogged the pressure becomes greater.

# Sample problems

- Suppose we are given:
  - $\eta = 0.027$
  - $l$= 2 cm
  - $r$= 0.0008 cm
  - P = 4000 dynes/cm2

Answer: 1.19 x 10^4 cm^3/s