Fundamental Concepts: Fluid Mechanics

Ann Kenimer
Texas A & M University

University Curriculum Development for Decentralized Wastewater Management

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Fluid

- A fluid is any non-solid material
- They include both liquids and gasses

Flow Rate

The flow rate is the amount of fluid that will pass through a plane over a unit of time

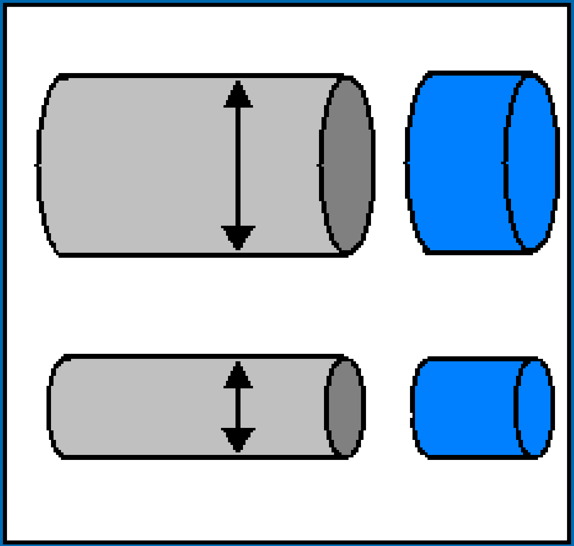
Flow Rate

$$Q = va$$

- Q = Flow Rate (length^3/time)
- v = Velocity (length/time)
- a = Area (length^2)

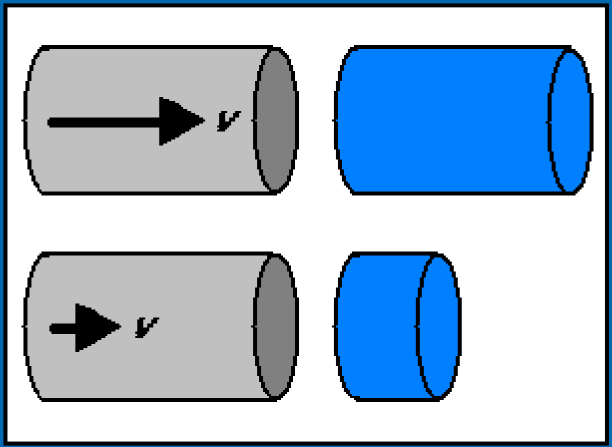
Flow Rate

Assuming equal velocities, more fluid will flow through a pipe with a **larger area** than that of a smaller diameter pipe



Flow Rate

Assuming equal area, more fluid will flow through a pipe when the fluid has a **greater velocity**

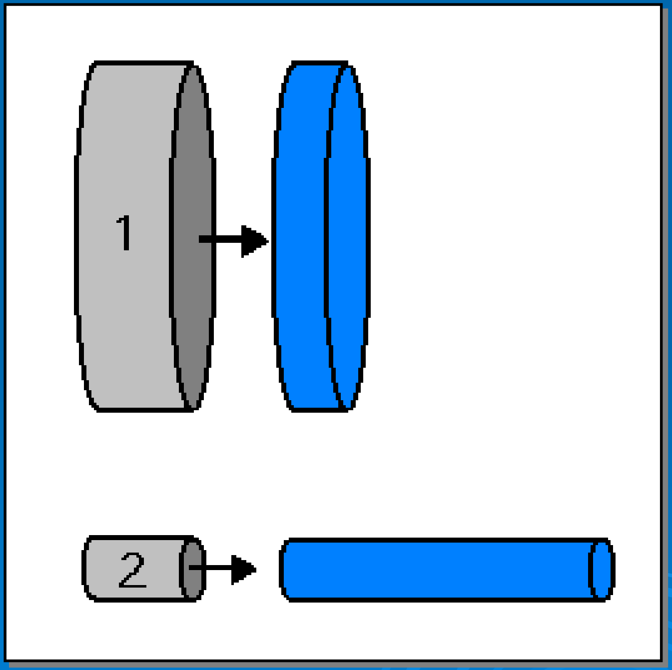


Flow Rate Example

Which pipe has the largest flow rate?

- $A_1 = 5\ m^2$
- $V_1 = .01\ m/s$

- $A_2 = .01 m^2$
- $V_2 = 5\ m/s$



Continuity

Flow through a pipe will follow the same mass balance rules as other systems:

What goes in, must go out -- unless material is stored in the system

$$\dot{m}_{in} = \dot{m}_{out}$$

Continuity

- The mass rate going into the system depends on two things:
  - The volume of liquid entering over time (Q)
  - The amount of matter present in a unit volume of the fluid (ρ)

Continuity

Mass flow rate =

Volumetric flow rate * density

$$\dot{m} = Q \times \rho$$

Continuity

Therefore:

$$\dot{m}_{in} = \dot{m}_{out}$$

$$Q_1 \times \rho_1 = Q_2 \times \rho_2$$

Continuity

Since the density of liquids remain constant, ρ falls out of the equation:

$$Q_1 = Q_2$$

$$\mathbf{A_1 * v_1 = A_2 * v_2}$$

Head

- The amount of mechanical energy per unit weight of material being pumped
- The height water would be pumped to with a given amount of energy
- Expressed in terms of that relative height of the liquid being considered

Total Head

- Static head plus
- Velocity head plus
- Frictional head

Static Head

- The difference in height between the free surface of the source and the free surface of the receiving body of water
- From the free surface of the initial source to the height of the outlet pipe

Velocity Head

- Energy of water movement
- If water has three feet of velocity head, it has enough energy to raise it three feet

Velocity Head

$$H_v = \frac{v^2}{2g}$$

- where
- H_v = velocity head (m or ft)
- v = flow velocity (m/s or ft/s)
- g = gravitational acceleration (m/s^2 or ft/s^2)

Frictional Head

- Energy lost to friction
- Darcy-Weisbach equation:

$$H_f = f\left(\frac{L}{D}\right)\left(\frac{v^2}{2g}\right)$$

where
H_f = frictional head (m or ft)
f = friction factor (dimensionless)
L = length of the pipe (m or ft)
D = Inside diameter of pipe (m or ft)
v = flow velocity (m/s or ft/s)
g = gravitational acceleration (m/s^2 or ft/s^2)