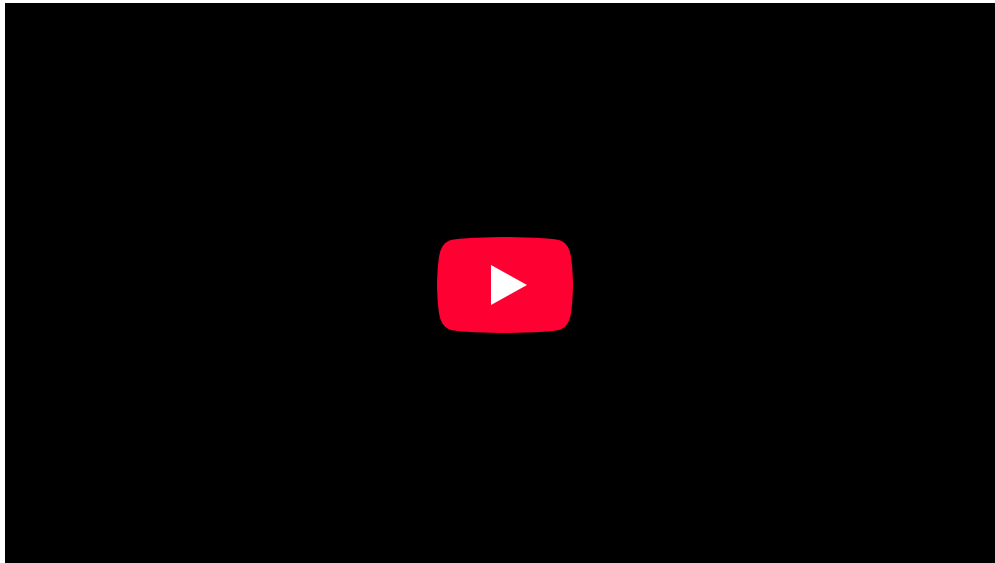


5.6.5: Fluids in Motion

learning objectives

- Determine the flow rate based on velocity and area or elapsed time and justify the use of continuity in expressing properties of a fluid and its motion

The flow rate of a fluid is the volume of fluid which passes through a surface in a given unit of time. It is usually represented by the symbol Q .




Sample Problem: Garden Hose

Water enters a typical garden hose of diameter 1.6 cm with a velocity of 3 m/s. Calculate the exit velocity of water from the garden hose when a nozzle of diameter 0.5 cm is attached to the end of the hose.

$$A_1 = \pi r_1^2 = \pi (.008 \text{ m})^2 = 2.01 \cdot 10^{-4} \text{ m}^2$$

$$A_2 = \pi r_2^2 = \pi (.0025 \text{ m})^2 = 1.96 \cdot 10^{-5} \text{ m}^2$$

$$A_1 v_1 = A_2 v_2 \Rightarrow v_2 = \left(\frac{A_1}{A_2} \right) v_1 = \left(\frac{2.01 \cdot 10^{-4}}{1.96 \cdot 10^{-5}} \right) 3 = 30.9 \frac{\text{m}}{\text{s}}$$


Continuity Equation for Fluids: A brief introduction to the Continuity Equation for Fluids.

Flow Rate

Volumetric flow rate is defined as

$$Q = v \times a, \quad (5.6.5.1)$$

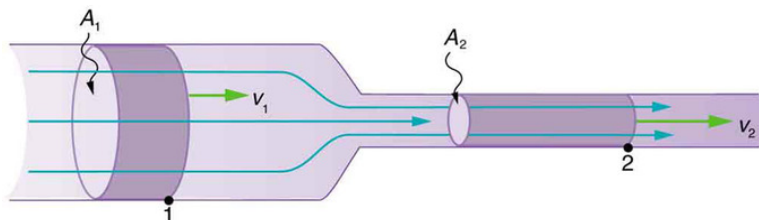
where Q is the flow rate, v is the velocity of the fluid, and a is the area of the cross section of the space the fluid is moving through. Volumetric flow rate can also be found with

$$Q = \frac{V}{t} \quad (5.6.5.2)$$

where Q is the flow rate, V is the Volume of fluid, and t is elapsed time.

Continuity

The equation of continuity works under the assumption that the flow in will equal the flow out. This can be useful to solve for many properties of the fluid and its motion:



Flow in = Flow out: Using the known properties of a fluid in one condition, we can use the continuity equation to solve for the properties of the same fluid under other conditions.

$$Q_1 = Q_2 \quad (5.6.5.3)$$

This can be expressed in many ways, for example: $A_1 v_1 = A_2 v_2$. The equation of continuity applies to any incompressible fluid. Since the fluid cannot be compressed, the amount of fluid which flows into a surface must equal the amount flowing out of the surface.

Applying the Continuity Equation

You can observe the continuity equation's effect in a garden hose. The water flows through the hose and when it reaches the narrower nozzle, the velocity of the water increases. Speed increases when cross-sectional area decreases, and speed decreases when cross-sectional area increases. This is a consequence of the continuity equation. If the flow Q is held constant, when the area A decreases, the velocity v must increase proportionally. For example, if the nozzle of the hose is half the area of the hose, the velocity must double to maintain the continuous flow.

Key Points

- Flow rate can be expressed in either terms of cross sectional area and velocity, or volume and time.
- Because liquids are incompressible, the rate of flow into an area must equal the rate of flow out of an area. This is known as the equation of continuity.
- The equation of continuity can show how much the speed of a liquid increases if it is forced to flow through a smaller area. For example, if the area of a pipe is halved, the velocity of the fluid will double.
- Although gases often behave as fluids, they are not incompressible the way liquids are and so the continuity equation does not apply.

Key Terms

- incompressible:** Unable to be compressed or condensed.
- continuity:** Lack of interruption or disconnection; the quality of being continuous in space or time.

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