WIND STUDY | Wind Study is intended for grades 5-8 and 8-11
Questions posted on: Monday Answers posted on: Friday
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2025Q4 MASS & ENERGY BALANCES WITH FLOW RATES

Hi students! In our last Wind Study, we explored mass and mass balances. This week, we're taking it a step further by diving into mass flow rates and volumetric flow rates and seeing how they are linked by density.

What Is Volume?

Last time, we learned that **mass** is how much matter an object contains. **Volume**, on the other hand, is how much space an object occupies. Think about water filling a swimming pool, air inflating a balloon, or juice poured into your favorite glass. Each of these examples takes up space—which is their volume! Volume is typically measured in cubic meters (m^3) or cubic feet (ft^3).

Mass Flow Rate vs. Volumetric Flow Rate

- **Mass flow rate** measures how much mass (like air or water) passes through a point over time, typically measured in seconds (s). Imagine placing a bucket on a scale and measuring how many kilograms of water pour in every second—that's your mass flow rate! Mass flow rate is often represented with the symbol $\dot{m}$, and is calculated using this formula:

$$\dot{m} = \frac{Mass\ (kg)}{Time\ (s)}$$

- **Volumetric flow rate** measures how much space (volume) a fluid—like air or water—occupies as it passes through a point over time, i.e., seconds (s). Imagine filling a bathtub and measuring how many cubic meters (m^3) of water pour in every second. That's your volumetric flow rate! Volumetric flow rate is often represented by the symbol Q, and is calculated using this formula:

$$Q = \frac{Volume\ (m^3)}{Time\ (s)}$$

Relationship Between Mass Flow Rate and Volumetric Flow Rate

Density is the key link between mass and volume. It describes how much mass is packed into a given space. Imagine two balloons of the same size—one filled with air and the other with water. Even though they're the same size (same volume), the water-filled balloon feels heavier. Why? Because water is denser that air! We represent density with the Greek letter ρ ("rho"). The equation for density is as follows:

$$Density\ =\ \rho\ = \frac{Mass\ (kg)}{Volume\ (m^3)}$$

Using density, we can link mass and volumetric flow rates using the following equation:

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

Where:

- $\dot{m}$ = mass flow rate (kg/s)
- ρ = density (kg/m³)
- Q = volumetric flow rate (m³/s)

Understanding mass and volumetric flow rates helps engineers design efficient wind turbines, airplanes, cars, plumbing systems, air conditioning units, and even kitchen faucets by accurately tracking how fluids (like air and water) move through them.

LEVEL 1 QUESTION (GRADES 5 – 8)

A fan moves 40 kilograms of air through a window in 8 seconds. Calculate the mass flow rate in pounds per second (lbs/s).

- **Hint:** 1 kg = 2.2 lbs

LEVEL 2 QUESTION (GRADES 8 –11)

A ventilation system moves 24 cubic meters (m^3) of air through a duct in 2 minutes. Given that air density is 1.225 kg/m^3, calculate the mass flow rate $\dot{m}$ in pounds per second (lbs/s).

- **Hint:** 1 kg = 2.2 lb, 1 min = 60 seconds (s)