

CHAPTER 9 | MECHANICAL PROPERTIES OF FLUIDS

9.3 Streamline Flow

Steady Flow, Streamlines, and
the Equation of Continuity

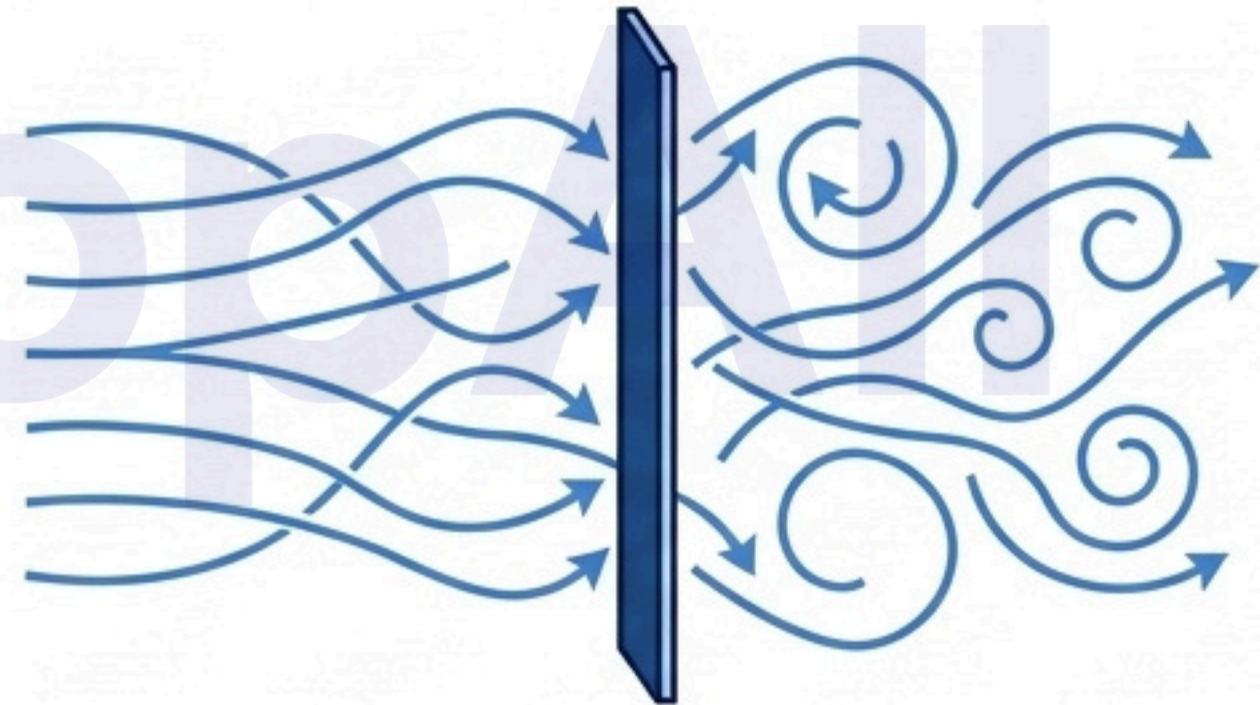
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The Anatomy of Steady Flow

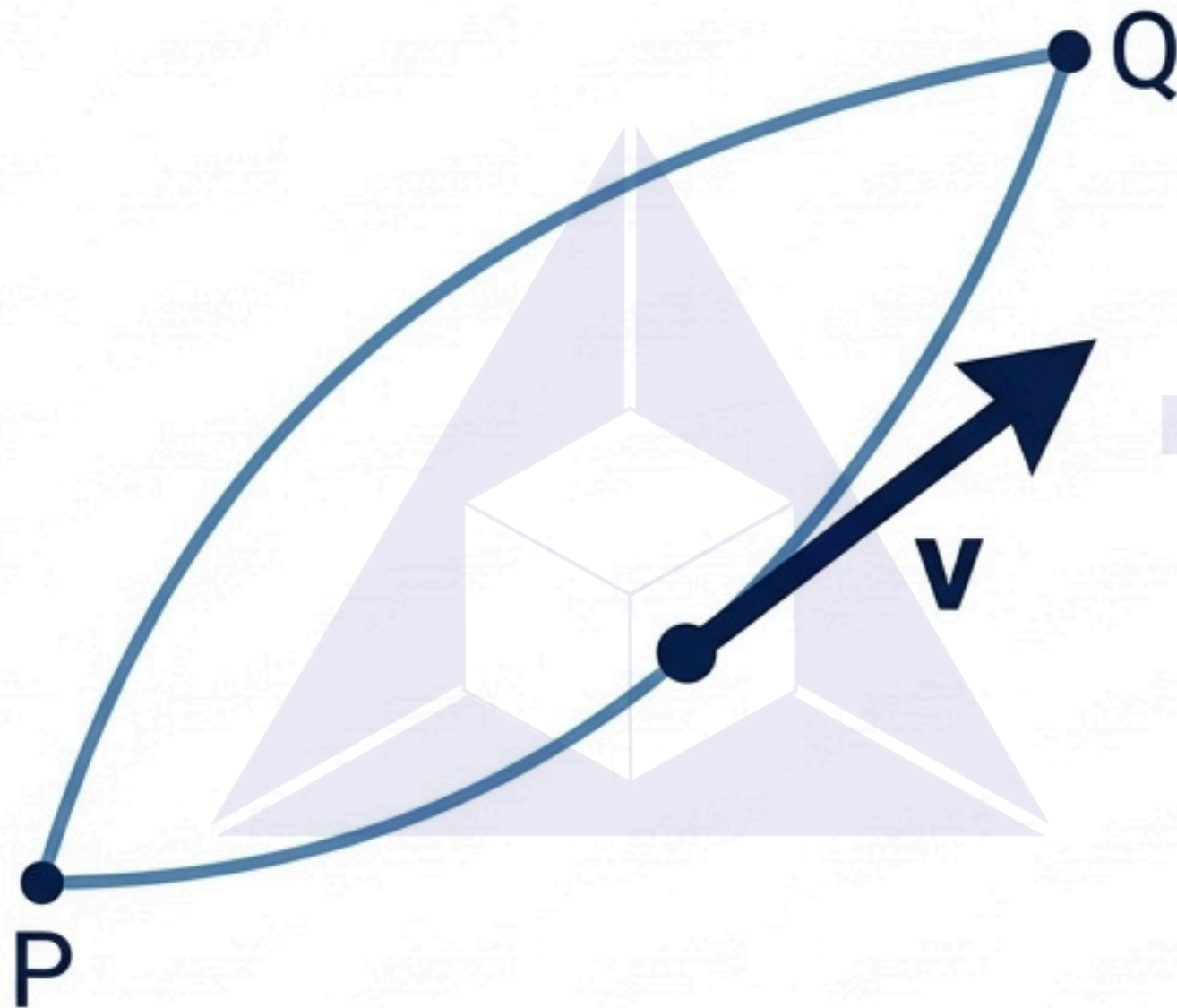
- Steady Flow: At any given point, the velocity of each passing fluid particle remains strictly constant in time.
- Particles follow predictable, smooth, non-intersecting paths.



Laminar Flow (Fig. 9.8a) – Smooth, sliding layers.



Turbulent Flow (Fig. 9.8b) – Chaotic, fluctuating paths.



DEFINITION

What is a Streamline?

- A streamline is a curve whose tangent at any point matches the direction of the fluid velocity at that point.
- It acts as a permanent map of fluid flow.

EXAM TIP: Two streamlines can NEVER cross! If they did, a particle at the intersection would have two different velocities at once—which is physically impossible in steady flow.



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$$E=mc^2$$



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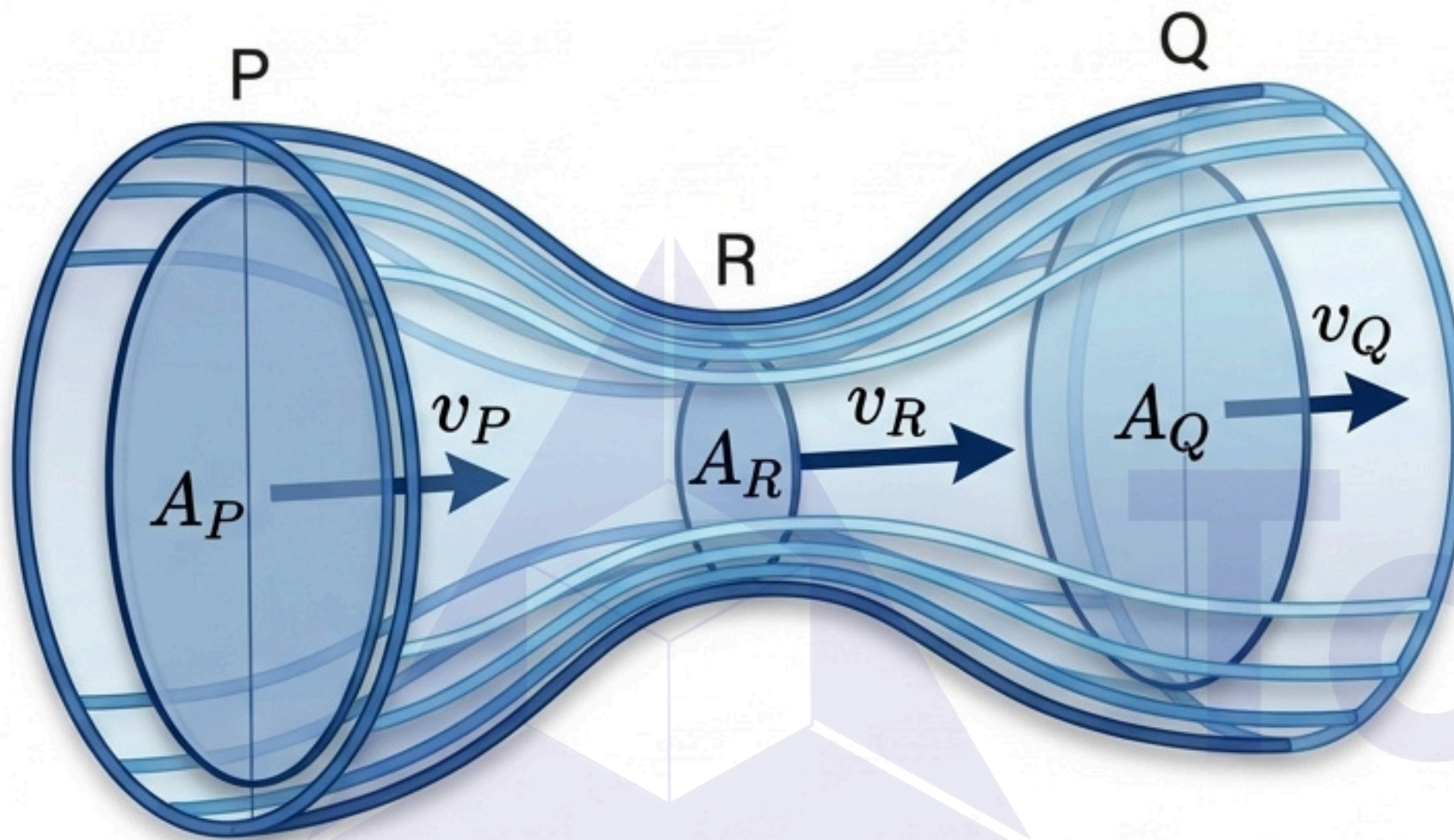


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Analyzing Flow Across Regions

- A bundle of adjacent streamlines forms a “tube” of flow.
- Let's observe three cross-sections: P, R, and Q.
- The Golden Rule: The mass of the liquid flowing into the tube must exactly equal the mass flowing out (no fluid crosses the tube walls).

$$\text{Eq (9.9): } \rho_P A_P v_P \Delta t = \rho_R A_R v_R \Delta t = \rho_Q A_Q v_Q \Delta t$$

CORE FORMULA

Conservation of Mass in Fluids

For incompressible fluids (like liquids), density is uniform: $\rho_P = \rho_R = \rho_Q$

Canceling constant density (ρ) and time (Δt) from our previous equation yields the **Continuity Equation**.

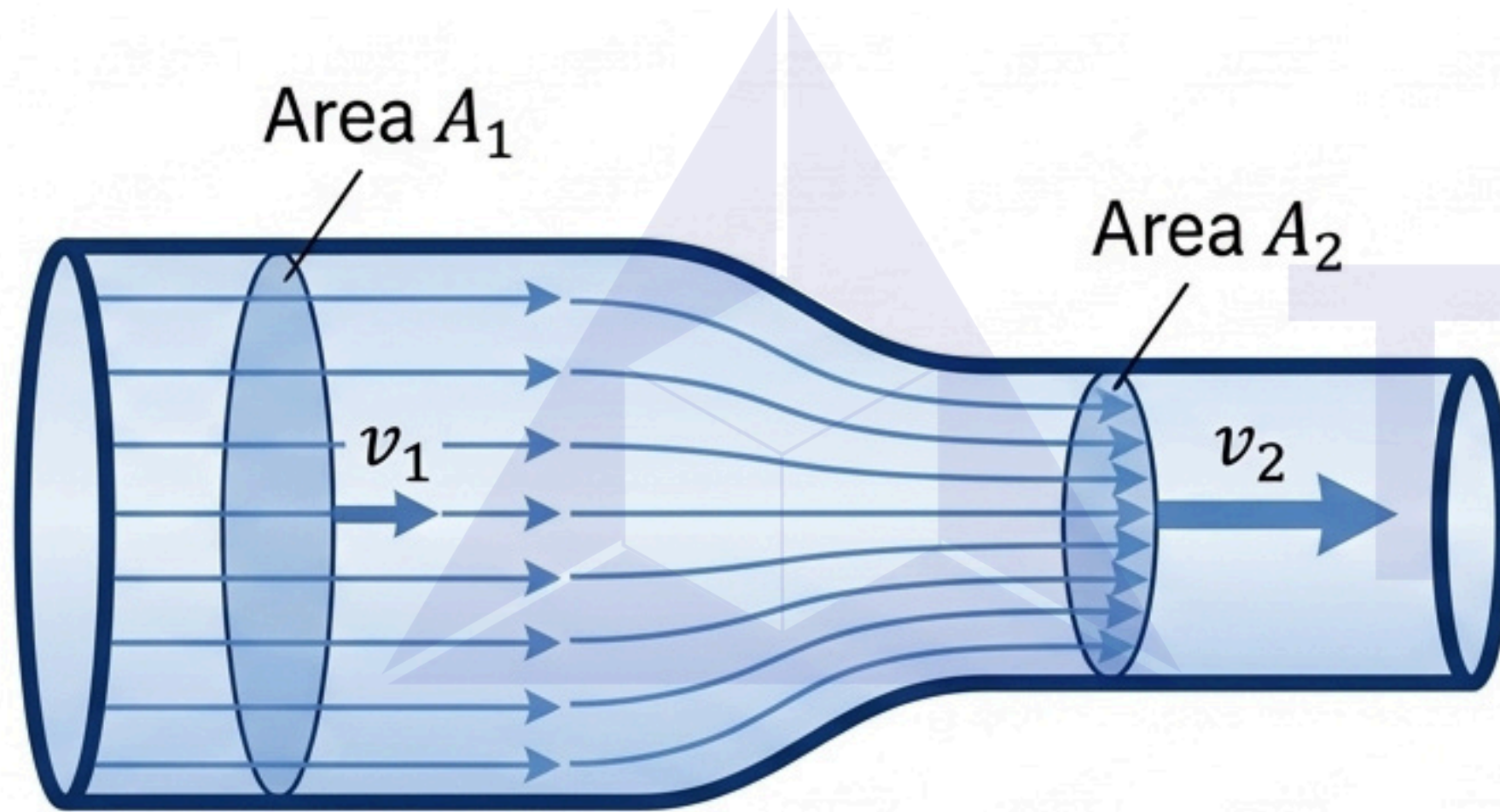
Equation of Continuity (9.10)

$$A_P v_P = A_R v_R = A_Q v_Q$$

This is the mathematical statement of conservation of mass in fluid flow.

APPLICATION

Why Narrow Pipes Flow Faster



$$Av = \text{constant (Eq. 9.11)}$$

- Av represents the volume flux (or flow rate).
- Since $A \times v$ must remain constant, Area and Velocity are inversely proportional.
- Result: Where the pipe narrows (Area $\downarrow$), the streamlines crowd together, forcing the velocity to increase (Speed $\uparrow$).

KEY TAKEAWAYS



Mastery Checklist

- ✓ **Steady Flow:** Velocity of passing particles at any point remains strictly constant in time.
- ✓ **Streamlines:** Tangent = velocity direction. Two lines can never intersect.
- ✓ **Continuity Equation:** $A_1v_1 = A_2v_2$. The ultimate mathematical proof of the conservation of mass.
- ✓ **Incompressible Rule:** $Av = \text{constant}$. A narrower area guarantees a higher fluid velocity.

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