

Garden Watering

Question:

- Water pours weakly from an open hose but sprays hard when you cover most of the end with your thumb. When is more water coming out of the hose?
- When the hose end is uncovered
- When your thumb covers most of the end

Observations About Garden Watering

- Faucets allow you to control water flow
- Faucets make noise when open
- Longer, thinner hoses deliver less water
- Water sprays faster from a nozzle
- Water only sprays so high
- A jet of water can push things over

Faucets: Limiting Flow

- Water's total energy limited by its pressure
 - Maximum kinetic energy limited by total energy
 - Maximum speed limited by kinetic energy
- Water has viscosity (friction within the fluid)
 - Water at the walls is stationary
 - Remaining water slows due to viscous forces

Viscous Forces

- Oppose relative motion within a fluid
- Similar to sliding friction – waste energy
- Fluids are characterized by viscosities

Hoses: Limiting Flow

- Water flow through a hose:
 - Increases as $1/\text{viscosity}$
 - Increases as $1/\text{hose length}$
 - Increases as pressure difference
 - Increases as $(\text{pipe diameter})^4$
- Poiseuille's law:

Water Flow in a Hose

- Flowing water loses energy to viscous drag
- Viscous drag increases with flow speed
 - Faster flow leads to more viscous energy loss
 - Faster flow causes quicker drop in pressure

Question:

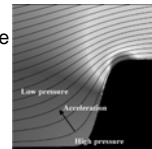
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Accelerating Flows

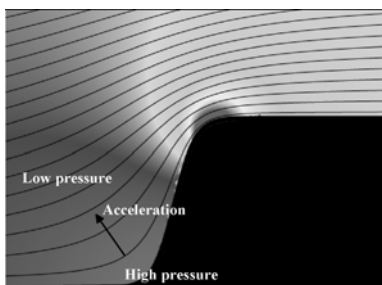
- Water in steady-state flow can accelerate
- Acceleration must be partly to the side
 - Forward acceleration would expand water
 - Backward acceleration would compress water
- Sideways acceleration
 - requires obstacles
 - causes pressure imbalances
 - causes speed changes

Outward Bend

- Deflecting water away from a surface
 - involves acceleration away from the surface
 - is caused by an outward pressure gradient
 - higher pressure near surface
 - lower pressure away from surface
 - causes water to travel slower near the surface

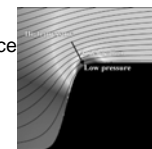


Outward Bend

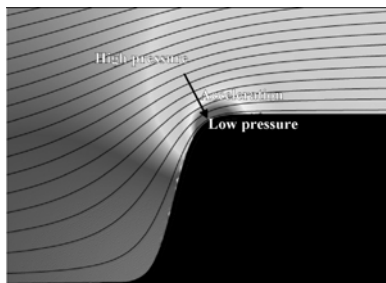


Inward Bend

- Deflecting water toward a surface
 - involves acceleration toward surface
 - is caused by inward pressure gradient
 - lower pressure near surface
 - higher pressure away from surface
 - causes water to travel faster near the surface

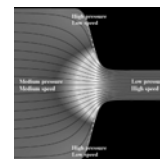


Inward Bend

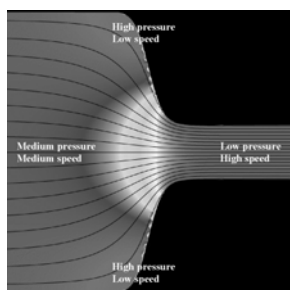


Nozzles: Speeding Water Up

- Water passing through a narrowing
 - speeds up
 - experiences pressure drop
- Water passing through a widening
 - slows down
 - experiences a rise in pressure



Nozzles



Types of Flow

- Laminar Flow
 - Nearby regions of water remain nearby
 - Viscosity dominates flow
- Turbulent Flow
 - Nearby regions of water become separated
 - Inertia dominates flow

Reynolds Number

- Reynolds number controls type of flow
- Below about 2300 : Laminar flow
 - Viscosity dominates
- Above about 2300 : Turbulent flow
 - Inertia dominates

Water and Momentum

- Water carries momentum
- Momentum is transferred by impulses:

$$\text{impulse} = \text{pressure imbalance} \cdot \text{surface area} \cdot \text{time}$$
- Large transfers: long times, large surface areas, or large pressure imbalances
- Moving water can be hard to stop

Summary About Garden Watering

- Total energy limits speed, height, pressure
- Nozzles exchange pressure for speed
- Viscosity wastes energy of water
- Turbulence wastes energy of water
- Moving water has momentum, too