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?

1. When the hose end is uncovered.
2. When your thumb covers most of the end.

Faucets: Limiting Flow

- Water's total energy is 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 their viscosities

Hoses: Limiting Flow

- Water flow through a hose:
  - Increases as 1/viscosity
  - Increases as 1/hose length
  - Increases as pressure difference
  - Increases as (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

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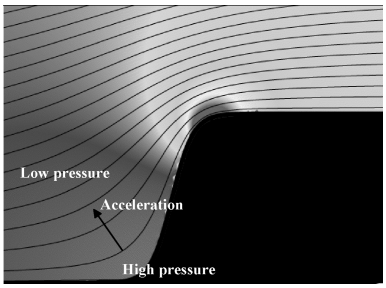
Accelerating Flows

- Water in steady-state flow can accelerate
- Acceleration must be partly to the side
  - Pure forward acceleration would expand water
  - Pure 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

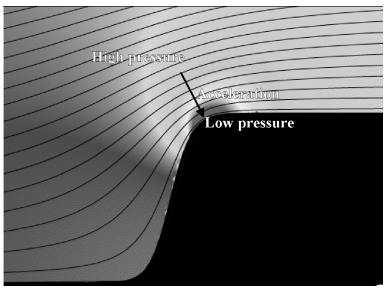
Outward Bend



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

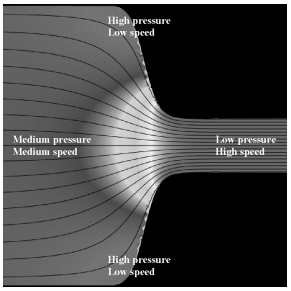
Inward Bend



Nozzles: Speeding Water Up

- Water passing through a narrowing
  - speeds up
  - experiences a drop in pressure
- 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:
  impulse = pressure imbalance · surface area · time
  - Large momentum transfers require either
    - long times
    - large surface areas
    - or large pressure imbalances
- Moving water can be hard to stop