

## 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 their 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:

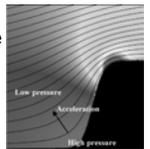
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## Accelerating Flows

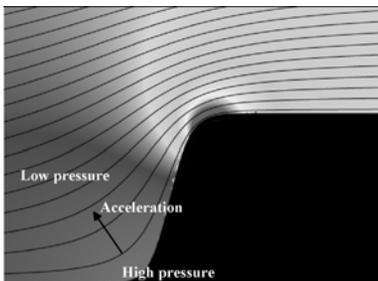
- Water in steady-state flow can accelerate
- Acceleration must be partly to the side
  - Forward acceleration would expand water
  - Backward acceleration would compress water
- Sideways acceleration
  - requires obstacles
  - causes pressure imbalances
  - causes speed changes

## 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

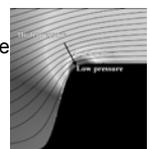


## Outward Bend

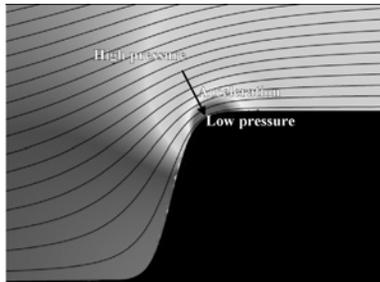


## Inward Bend

- 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

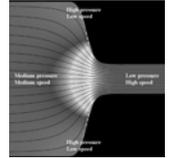


## Inward Bend

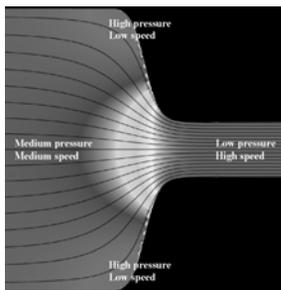


## Nozzles: Speeding Water Up

- 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