Garden Watering

Turn off all electronic devices

Observations about Garden Watering

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

6 Questions about Garden Watering

1. How does a faucet control flow?
2. How much does the diameter of a hose matter?
3. Why does water pour gently from an open hose?
4. Why does water spray fast from a nozzle?
5. What causes hissing in a faucet, hose, or nozzle?
6. Why do pipes rattle when you close the faucet?

Question 1

Q: How does a faucet control flow?

A: Water's energy and viscosity limit the flow

- Water traverses a narrow passage in the faucet
- Total energy limits flow speed through passage
  - The water turns its total energy into kinetic energy,
  - but its peak speed is limited by its initial pressure
- Motion near surfaces slows water in the passage
  - Because water at the passage walls is stationary,
  - viscous forces within the water slow all of it

Viscous Forces and Viscosity

- Viscous forces
  - oppose relative motion within a fluid
  - and are similar to sliding friction: they waste energy
- Fluids are characterized by their viscosities
  - the measure of the strength of the viscous forces
  - and caused by chemical interactions within the fluids

Question 2

Q: How much does the diameter of a hose matter?

A: It matters a surprisingly large amount

- Water flow through a hose is proportional to
  - pressure difference between hose ends
  - 1/viscosity
  - 1/hose length
  - (hose diameter)^4

$$\text{flow rate} = \frac{\pi \cdot \text{pressure difference} \cdot \text{hose diameter}^4}{128 \cdot \text{hose length} \cdot \text{viscosity}}$$

Question 3

Q: Why does water pour gently from an open hose?
A: The free-flowing water wastes most of its energy

- Viscous effects in the hose
  - waste water's total energy as thermal energy
  - and become stronger with increased flow speed
- Increasing the speed of the flow in the hose
  - increases the energy wasted by each portion of water
  - makes the loss of pressure more rapid

Question 4

Q: Why does water spray fast from a nozzle?
A: The nozzle causes water to turn PPE into KE

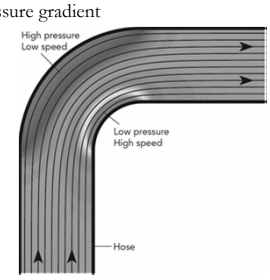
- As water flow necks down in a nozzle, it must
  - speed up to avoid a "traffic jam"
  - have a pressure imbalance pushing it forward
  - be flowing from higher pressure to lower pressure

Making Water Accelerate

- Even in steady-state, water can accelerate
  - but forward acceleration would leave gaps
  - and backward acceleration would cause jams,
  - so the acceleration must involve turning.
- Acceleration toward the side (turning)
  - requires obstacles,
  - and involves pressure imbalances
  - and changes in speed.

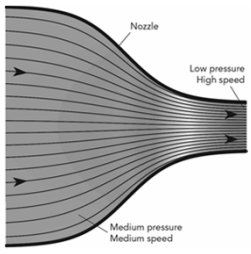
Bending the Flow in a Hose

- Bending the flow requires a pressure imbalance
  - The water accelerates toward lower pressure
- Flow in bent hose develops a pressure gradient
  - higher pressure & lower speed on the outside of the bend
  - lower pressure & higher speed on the inside of the bend
  - and water accelerates from high pressure to lower pressure



Speeding the Flow in a Nozzle

- Speeding the flow requires a pressure imbalance
  - The water accelerates toward lower pressure
- Flow in nozzle develops a pressure gradient
  - higher pressure & lower speed at start of nozzle
  - lower pressure & higher speed as the nozzle narrows
  - and water accelerates from high pressure to lower pressure



Question 5

Q: What causes hissing in a faucet, hose, or nozzle?
A: Water can become turbulent and produce noise.

- We've been examining laminar flow
  - in which viscosity dominates the flow's behavior
  - and nearby regions of water remain nearby
- Now we'll also consider turbulent flow
  - in which inertia dominates the flow's behavior
  - and nearby regions of water become separated
- Turbulent flow produces thermal energy

Reynolds Number

- The flow type depends on the Reynolds number

$$\text{Reynolds number} = \frac{\text{inertial influences}}{\text{viscous influences}} = \frac{\text{density} \cdot \text{obstacle length} \cdot \text{speed}}{\text{viscosity}}$$

- Below ~2300 viscosity wins, so flow is laminar
- Above ~2300 inertia wins, so flow is turbulent

Question 6

Q: Why do pipes rattle when you close the faucet?
A: Moving water carries momentum.

- Water transfers its momentum via impulses:

  impulse = pressure · surface area · time
- Large momentum transfers require
  - large pressures, large surface areas, or long times.
- Moving water can be surprisingly hard to stop
  - Sudden stops can result in enormous pressures

Summary about Garden Watering

- Total energy limits speed, height, and pressure
- Bending water flows develop pressure gradients
- Nozzles exchange pressure for speed
- Viscosity wastes flowing water's total energy
- Turbulence wastes flowing water's total energy
- Wasted total energy because thermal energy
- Moving water has momentum, too