Garden Watering 1

Garden Watering

Turn off all electronic devices

Garden Watering 2

Observations about Garden Watering

A faucets let you to control the flow of water through a hose
Faucets can make noise when water is flowing through them
Longer, thinner hoses deliver less water
Water sprays at high speed from a nozzle
Water sprays only to a certain height
A jet of water can push things over

Garden Watering 3

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?

Garden Watering 4

Question 1

Q: How does a faucet control flow?
A: Water's finite ordered energy and its viscosity limit its flow

Inside the faucet, water traverses a narrow passage
Water's finite ordered energy limits its flow speed in that passage
- Water's peak speed in the passage is limited by its ordered energy
- Water's flow rate is constrained by its peak speed and the passage geometry

Wasted energy further reduces water's flow speed in the passage
- Water near the walls slows due to viscous effects that waste ordered energy
- Turbulence triggered by obstacles in water's path also waste ordered energy

Garden Watering 5

Viscous Forces and Viscosity

Viscous forces oppose relative motion within a fluid
- Layers of a fluid in relative motion exert viscous forces on one another
- Like sliding friction, viscous forces waste energy as thermal energy
- Unlike sliding friction, viscous forces increase as relative velocity increases

Fluids are characterized by their viscosities
- Viscous forces are proportional to a fluid's viscosity
- A fluid's viscosity results from chemical interactions within that fluid

Garden Watering 6

Question 2

Q: How much does the diameter of a hose matter?
A: The flow through a hose increases very rapidly with diameter

Because of viscous forces, water does not coast through a hose
- It wastes ordered energy, so it requires work to move at constant velocity

Water flow through a hose is proportional to:
- pressure difference between hose ends
- 1/hose length
- 1/viscosity
- (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 fast-moving water wastes most of its ordered energy

Viscous effects in the hose
- waste water's ordered energy as thermal energy
- become stronger with increased flow speed in the hose

Increasing the speed of the flow in the hose
- increases the ordered energy wasted by each portion of water
- increases the rate at which pressure decreases along the length of the hose

Question 4

Q: Why does water spray fast from a nozzle at the end of a hose?

A: The slow-moving water retains most of its ordered energy

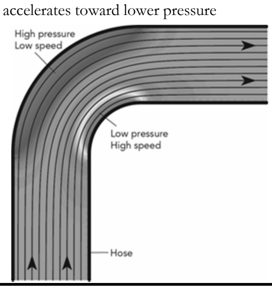
The nozzle restricts water flow in the hose
- Constrained by the nozzle, water moves relatively slowly through the hose
- Viscous effects waste relatively little of the water's ordered energy
- The water's pressure decreases only slightly in the (level) hose

As it flows through the nozzle, water converts its PPE to KE
- Water must speed up in nozzle's narrow neck to avoid a "traffic jam"
- Water accelerates forward from higher pressure to lower pressure
- Water's pressure decreases and its speed increases in the nozzle

Bending the Flow in a Hose

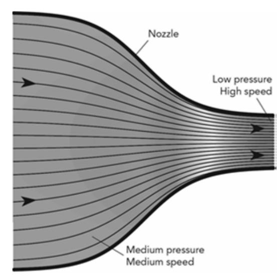
For water to accelerate in a level hose,
- it needs a bend or a change in hose-diameter to avoid "traffic jams" or "gaps"
- it develops a pressure gradient and accelerates toward lower pressure

In a bent level hose, flowing water
- develops a pressure gradient
  - higher pressure and lower speed on the outside of the bend
  - lower pressure and higher speed on the inside of the bend
- accelerates toward lower pressure
- follows the bend in the hose



Speeding the Flow in a Nozzle

In a nozzle, flowing water
- develops a pressure gradient
  - higher pressure and lower speed at entry to the nozzle's neck
  - lower pressure and higher speed exit from the nozzle's neck
- accelerates toward lower pressure
- necks down and speeds up



Question 5

Q: What causes hissing in a faucet, hose, or nozzle?

A: When water becomes turbulent, it often produces noise.

Until now, we've considered only laminar flow, in which
- nearby regions of water remain nearby
- streamlines are meaningful
- viscosity dominates the flow's behavior, keeping it orderly

Now we'll also consider turbulent flow, in which
- nearby regions of water become separated to arbitrary distances
- streamlines are no longer meaningful
- inertia dominates the flow's behavior, tearing it into shreds

Turbulent flow converts ordered energy into thermal energy

Reynolds Number

Type of flow often depends on the Reynolds number

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

Viscous influences favor laminar flow
- At low Reynolds number (< ~2300), viscous ordering wins
- andflow tends to remain laminar

Inertial influences favor turbulent flow
- At high Reynolds number (> ~2300), inertial disordering wins
- and flow tends to become turbulent

Question 6

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

Water transfers its momentum via impulses:

$$\text{impulse} = \text{force} \cdot \text{time}$$
$$= (\text{pressure} \cdot \text{surface area}) \cdot \text{time}$$

Stopping a column of water requires a pressure gradient

- The pressure at the front of the column can become very large
- If the column is long, fast-moving, and stops suddenly, it can break a pipe

Summary about Garden Watering

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