Water Distribution

Turn off all electronic devices

Observations about Water Distribution

- Water is pressurized in the pipes
- Higher-pressure water can spray harder and higher
- Water is often pressurized by pumps
- Water is often stored in tall water towers

4 Questions about Water Distribution

1. Why does water move through level pipes?
2. How can you produce pressurized water?
3. Where does the work you do pumping water go?
4. As water flows, what happens to its energy?

Question 1

Q: Why does water move through level pipes?

A: It exhibits inertia and it accelerates toward lower pressure

- Water, like all fluids, obeys Newton's laws
  - When water experiences zero net force, it coasts
  - When water experiences a net force, it accelerates
  - Pressure imbalances exert net forces on portions of water
  - Water accelerates toward lower pressure

Question 2

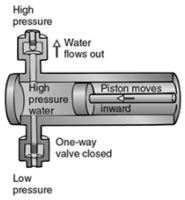
Q: How can you produce pressurized water?

A: Push inward on the water, using a surface

- To pressurize water, confine it and squeeze inward on it
  - As you push inward on the water,
  - it pushes outward on you (Newton's third law).
  - Water's outward push is produced by its pressure,
  - so the water's pressure rises as you squeeze it harder.
- Like all liquids, water is nearly incompressible
  - Its volume remains constant as its pressure increases

Pumping Water (no gravity)

- To deliver pressurized water to a pipe,
  - squeeze the water inward to increase its pressure
  - until that pressure exceeds the pressure in the pipe and opens a valve
  - The water will then accelerate toward the pipe
  - and pressurized water will flow through the valve and into the pipe!



Pumping Requires Work

- You do work as you pump water into the pipe
  - You squeeze the water inward – the force (pressure · area),
  - and the water moves inward – the distance.
  - The work you do pumping water is:

    work = force · distance

    work = (pressure · area) · distance

    work = pressure · (area · distance)

    work = pressure · volume
- The pressurized water carries your work with it
- We'll call this work pressure potential energy (PPE)

Question 3

Q: Where does the work you do pumping water go?
A: To the water at the delivery-end of the pipe

- Pressure potential energy is unusual because
  - it's not really stored in the pressurized water,
  - it's promised by the water's pressure source.
  - If the pressure source vanishes, so does pressure potential energy.
- In steady state flow (SSF),
  - which is steady flow in motionless surroundings,
  - promised energy is as good as stored energy,
  - so pressure potential energy (PPE) is meaningful.

Question 4

Q: As water flows, what happens to its energy?
A: That energy is converted between several forms

- In SSF, water flows along streamlines
- Water flowing along a single streamline in SSF
  - has both PPE and kinetic energy (KE),
  - must have a constant total energy per volume,
  - and obeys Bernoulli's equation (no gravity):

$$\frac{\text{PPE}}{\text{Volume}} + \frac{\text{KE}}{\text{Volume}} = \frac{\text{Constant}}{\text{Volume}}$$

Gravity Causes Pressure Gradients

- Like air in the atmosphere, water in a pipe
  - has a density and a weight per volume
  - has a pressure gradient when it is at equilibrium
  - Its pressure decreases with altitude
  - That pressure gradient supports its weight
- Water has gravitational potential energy (GPE)
  - Its GPE increases with altitude

Energy and Bernoulli (with gravity)

- Water flowing along a single streamline in SSF
  - has PPE, KE, and GPE,
  - must have a constant total energy per volume,
  - and obeys Bernoulli's equation (with gravity)

$$\frac{\text{PPE}}{\text{Volume}} + \frac{\text{KE}}{\text{Volume}} + \frac{\text{GPE}}{\text{Volume}} = \frac{\text{Constant}}{\text{Volume}}$$

Energy Transformations (part 1)

- As water flows upward in a uniform pipe,
  - its speed can't change (a jam or a gap would form),
  - so its gravitational potential energy increases
  - and its pressure potential energy decreases.
- As water flows downward in a uniform pipe,
  - its speed can't change,
  - so its gravitational potential energy decreases
  - and its pressure potential energy increases.

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Energy Transformations (part 2)

- As water rises upward from a fountain nozzle,
  - its pressure stays constant (atmospheric),
  - so its gravitational potential energy increases
  - and its kinetic energy decreases.
- As water falls downward from a spout,
  - its pressure stays constant (atmospheric),
  - so its gravitational potential energy decreases
  - and its kinetic energy increases.

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Energy Transformations (part 3)

- As water sprays horizontally from a nozzle,
  - its height is constant,
  - so its kinetic energy increases
  - and its pressure potential energy decreases.
- As a horizontal stream of water hits a wall,
  - its height is constant,
  - so its kinetic energy decreases
  - and its pressure potential energy increases.

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Summary about Water Distribution

- Water's energy remains constant during SSF
- Water's energy changes form as it
  - flows upward or downward inside pipes,
  - rises or falls in open sprays,
  - and shoots out of nozzles or collides with objects.
- Water distribution can driven by
  - pressurized water (PPE)
  - elevated water (GPE)
  - fast-moving water (KE)