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 also 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

In level pipes, those pipes support water's weight
- Water can still experience net forces due to pressure imbalances
- Water accelerates toward lower pressure

Question 2

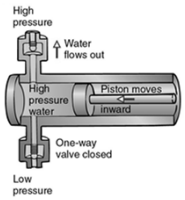
Q: How can you produce pressurized water?
A: Push inward on the water, using a surface

To pressurize water, confine it and squeeze inward on it
- As you push inward on water, it pushes outward on you (Newton's 3rd 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,
- confine a portion of water in a container with its valves closed
- squeeze the water inward until its pressure exceeds that in the pipe
- open the valve to allow the water to flow into the pipe
- let the pressurized water accelerate toward and flow into the pipe



Pumping Requires Work

You do work as you pump water into the pipe

- You squeeze the water inward with a force that is pressure·area,
- The water moves inward a distance in the direction of your force.
- The work you do on the water as you pump it in this fashion is:

work = force · distance

work = (pressure · area) · distance

work = pressure · (area · distance)

work = pressure · volume

The pressurized water you pump carries your work with it

We will 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 is not actually stored within the pressurized water
- it is provided on-demand by the water's source of pressure (e.g., a pump)
- If the source of pressure vanishes, so does water's pressure potential energy.

Pressure potential energy is meaningful in steady state flow

- Steady state flow (SSF) is steady flow through motionless surroundings
- SSF is time-independent, so sources of pressure never vanish or appear
- so pressure potential energy (PPE) is as good as a true potential energy

Question 4

Q: As water flows, what happens to its energy?

A: Energy is often converted between kinetic and potential forms

In SSF, water flows along streamlines—each the path of a single drop

Water flowing along a single horizontal streamline in steady state flow

- has pressure potential energy (PPE) and kinetic energy (KE)
- has an ordered energy per volume that remains constant
- obeys Bernoulli's equation (omitting gravity for now):

$$\frac{\text{Ordered energy}}{\text{Volume}} = \frac{\text{PPE}}{\text{Volume}} + \frac{\text{KE}}{\text{Volume}} = \text{Constant (along a streamline)}$$

Gravity Causes Pressure Gradients

Like air in the atmosphere, water in a pipe

- has a pressure that decreases with altitude at equilibrium (a pressure gradient)
- and that pressure gradient supports its weight

Water has gravitational potential energy (GPE)

- The GPE per volume of water increases with altitude

Energy and Bernoulli (with gravity)

Water flowing along a single streamline in steady state flow

- has PPE, GPE, and KE
- has an ordered energy per volume that remains constant
- obeys Bernoulli's equation (with gravity)

$$\frac{\text{Ordered energy}}{\text{Volume}} = \frac{\text{PPE}}{\text{Volume}} + \frac{\text{KE}}{\text{Volume}} + \frac{\text{GPE}}{\text{Volume}} = \text{Constant (along a streamline)}$$

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)