What are Voltage and Current?

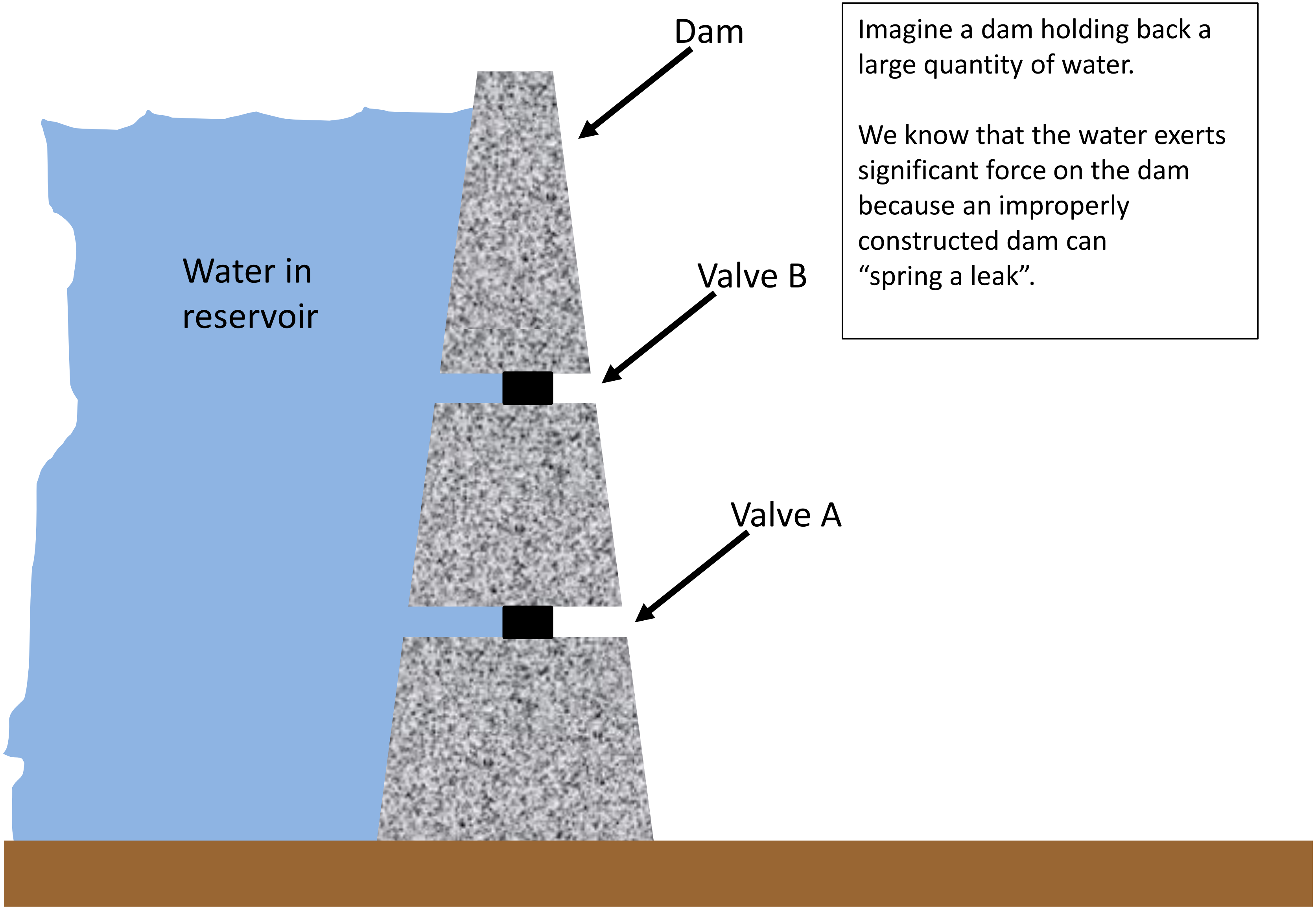
An attempt to convey some basic intuition about electricity.

Unit-01 of N

Concepts and Objectives

By the end of this section you should have an understanding of the following:

1. How is basic electricity is similar to basic water flow?
2. What are the electrical quantities *Voltage*, *Current*, and *Resistance*?
3. Of *Voltage*, *Current*, and *Resistance*, which is:
    1. A *forcing function* that drives a system?
    2. A *characteristic of the system* under study?
    3. A *response* of a given system to a given forcing function?
4. How does one measure some of these fundamental electrical quantities?
5. We'll mention *Digital Multi-Meters* (*DMMs*) but will explain their operation more in lab exercises.

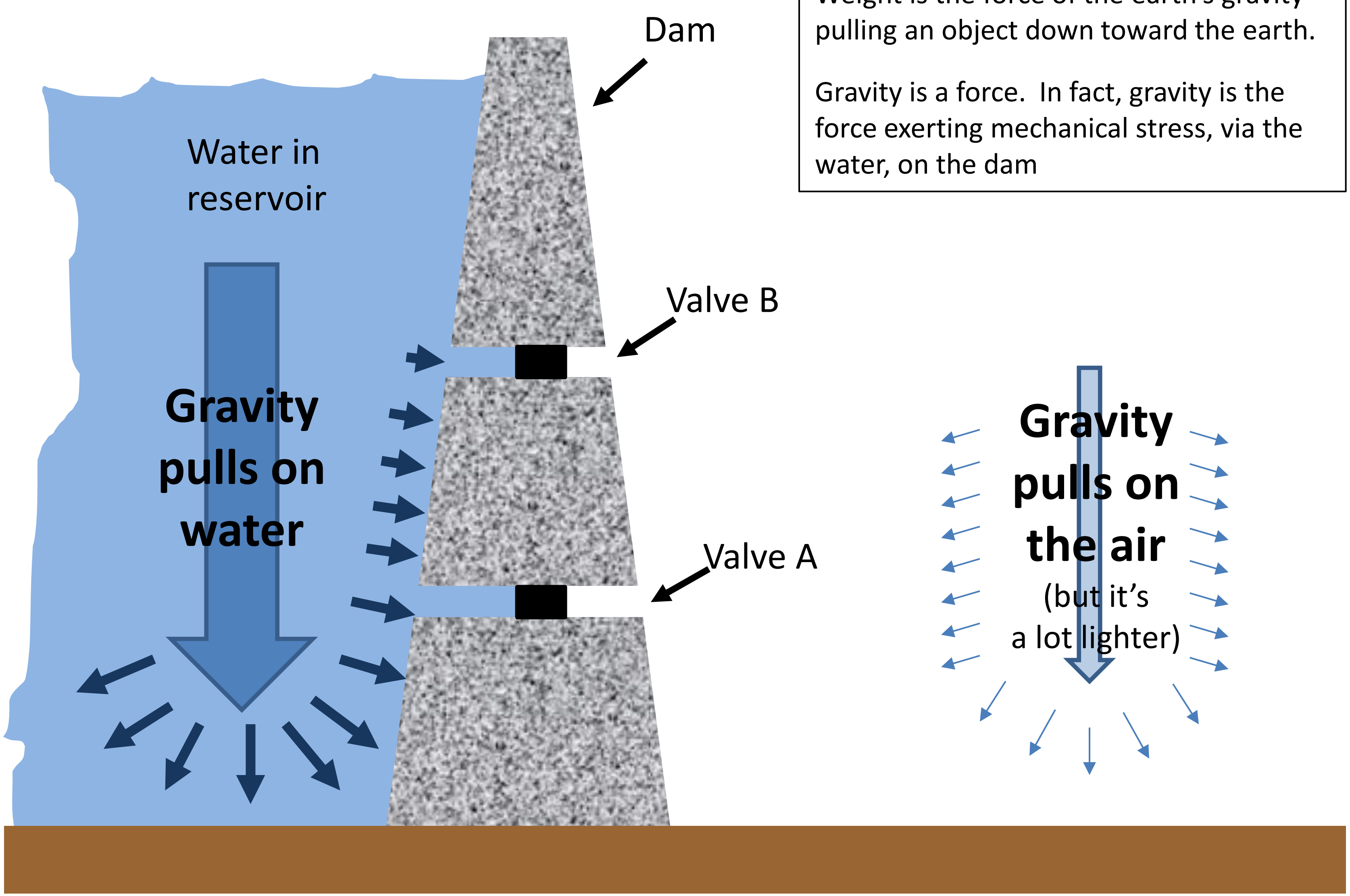


Imagine a dam holding back a large quantity of water.

We know that the water exerts significant force on the dam because an improperly constructed dam can "spring a leak".

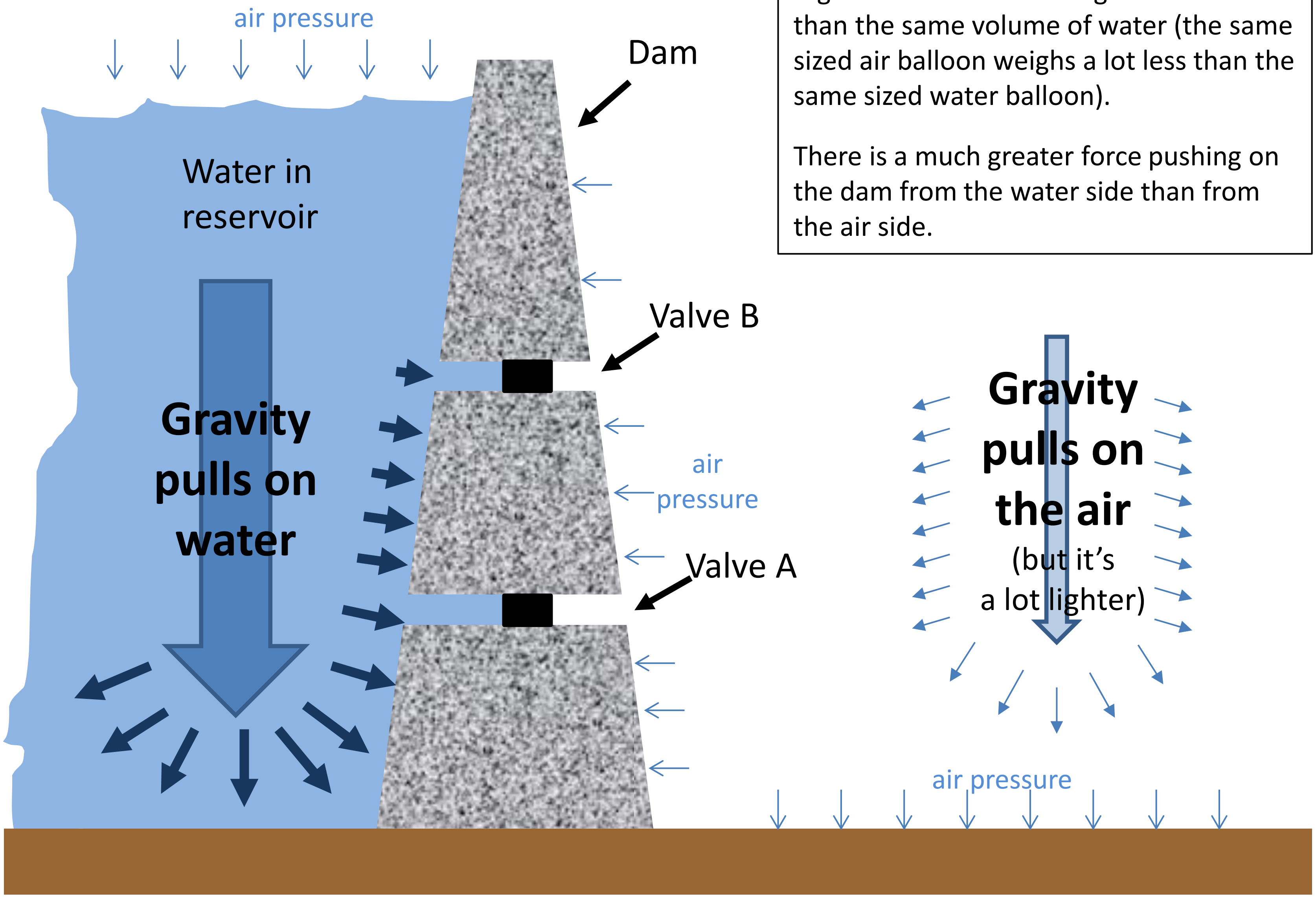
Weight is the force of the earth's gravity pulling an object down toward the earth.

Gravity is a force. In fact, gravity is the force exerting mechanical stress, via the water, on the dam



A given volume of air weighs a lot less than the same volume of water (the same sized air balloon weighs a lot less than the same sized water balloon).

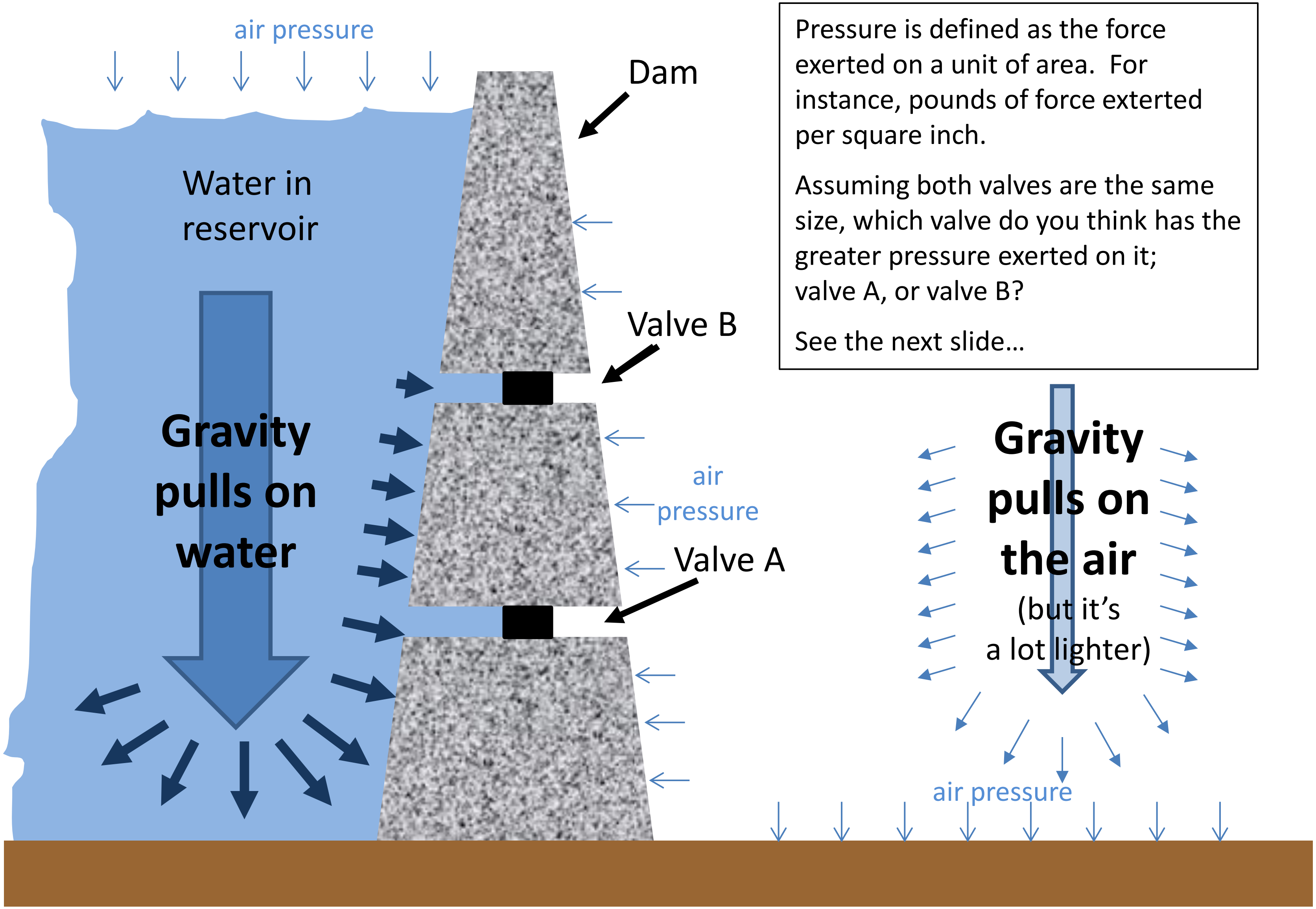
There is a much greater force pushing on the dam from the water side than from the air side.



Pressure is defined as the force exerted on a unit of area. For instance, pounds of force exterted per square inch.

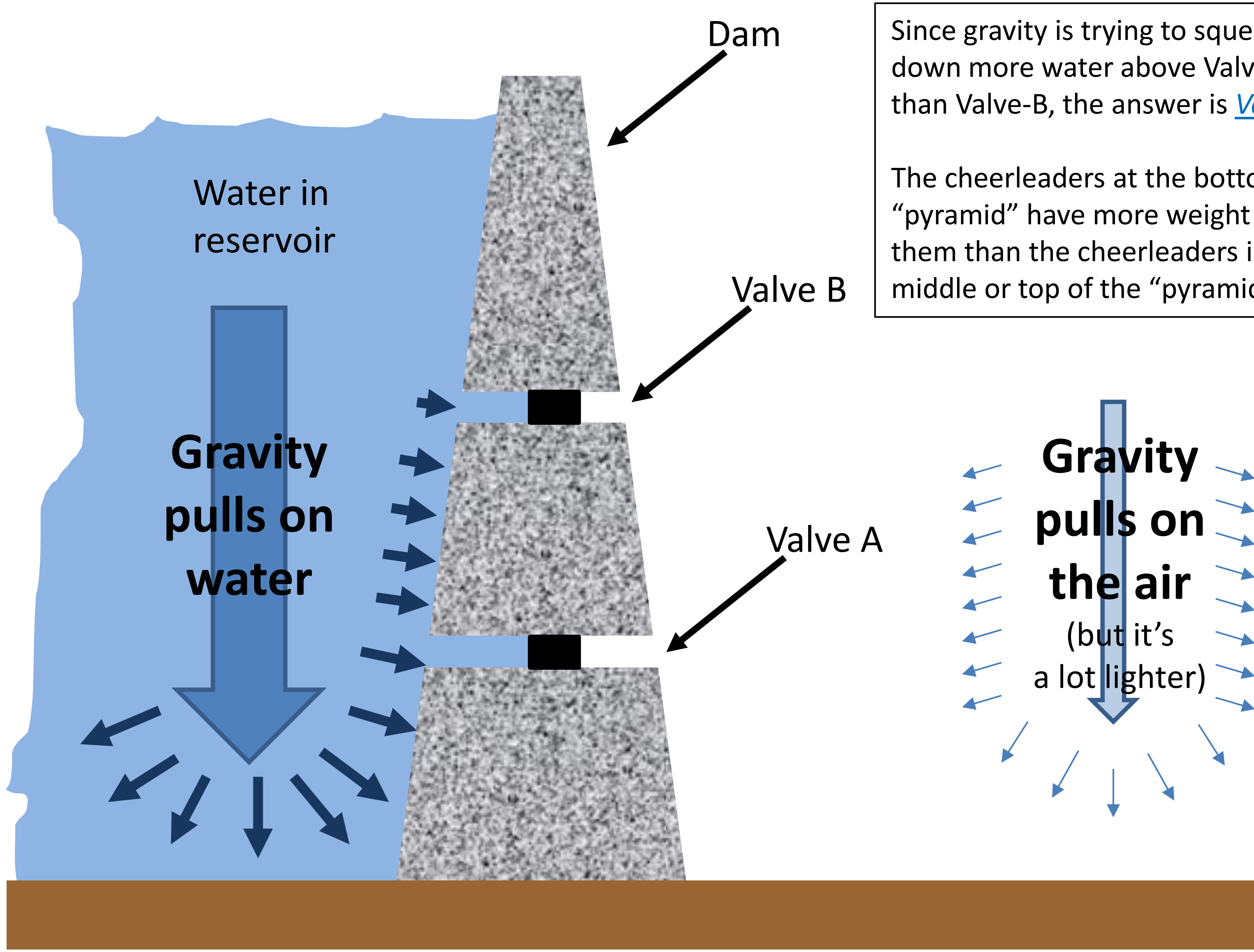
Assuming both valves are the same size, which valve do you think has the greater pressure exerted on it; valve A, or valve B?

See the next slide…

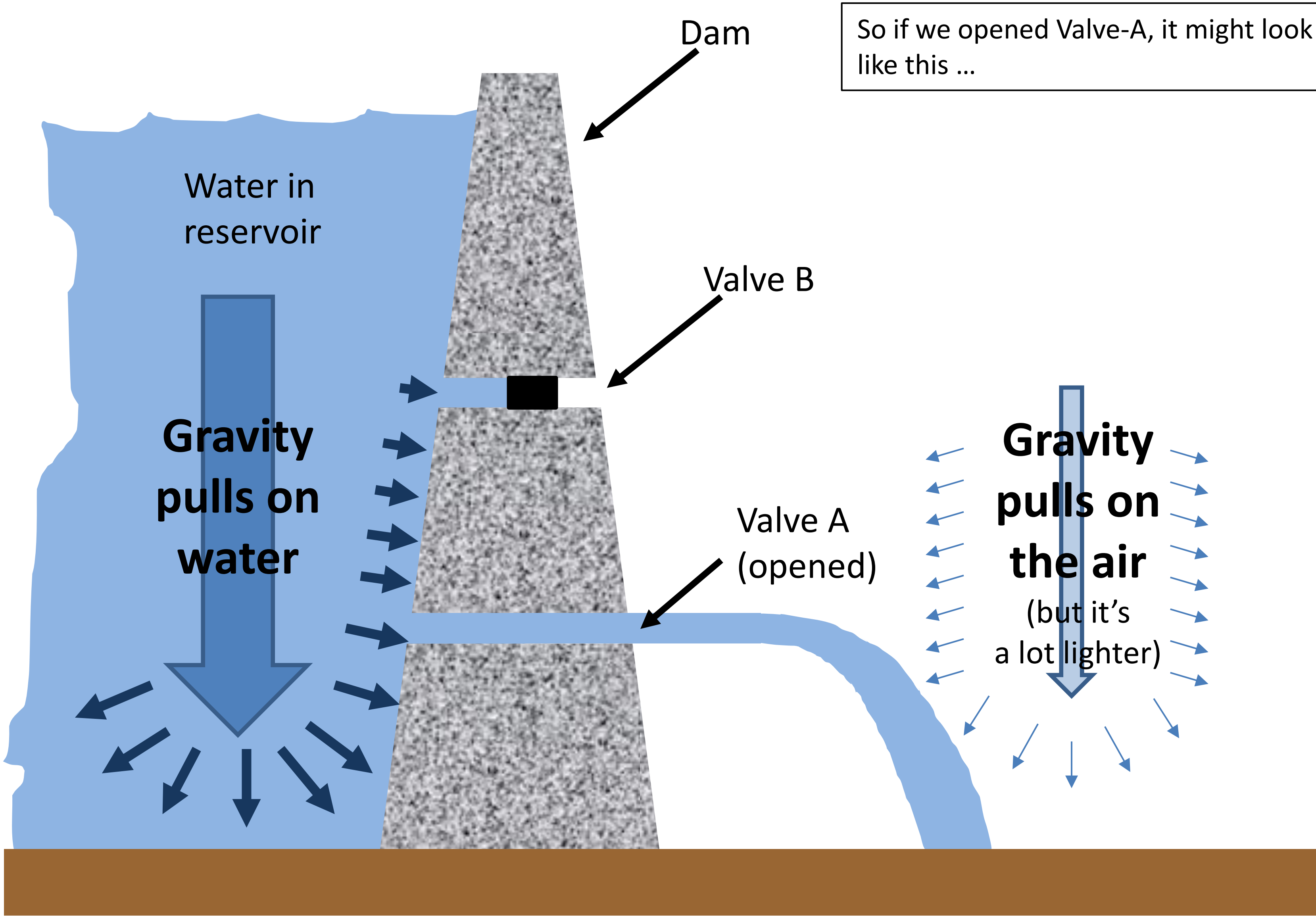


Since gravity is trying to squeeze down more water above Valve-A than Valve-B, the answer is *Valve-A*.

The cheerleaders at the bottom of a "pyramid" have more weight on them than the cheerleaders in the middle or top of the "pyramid"…

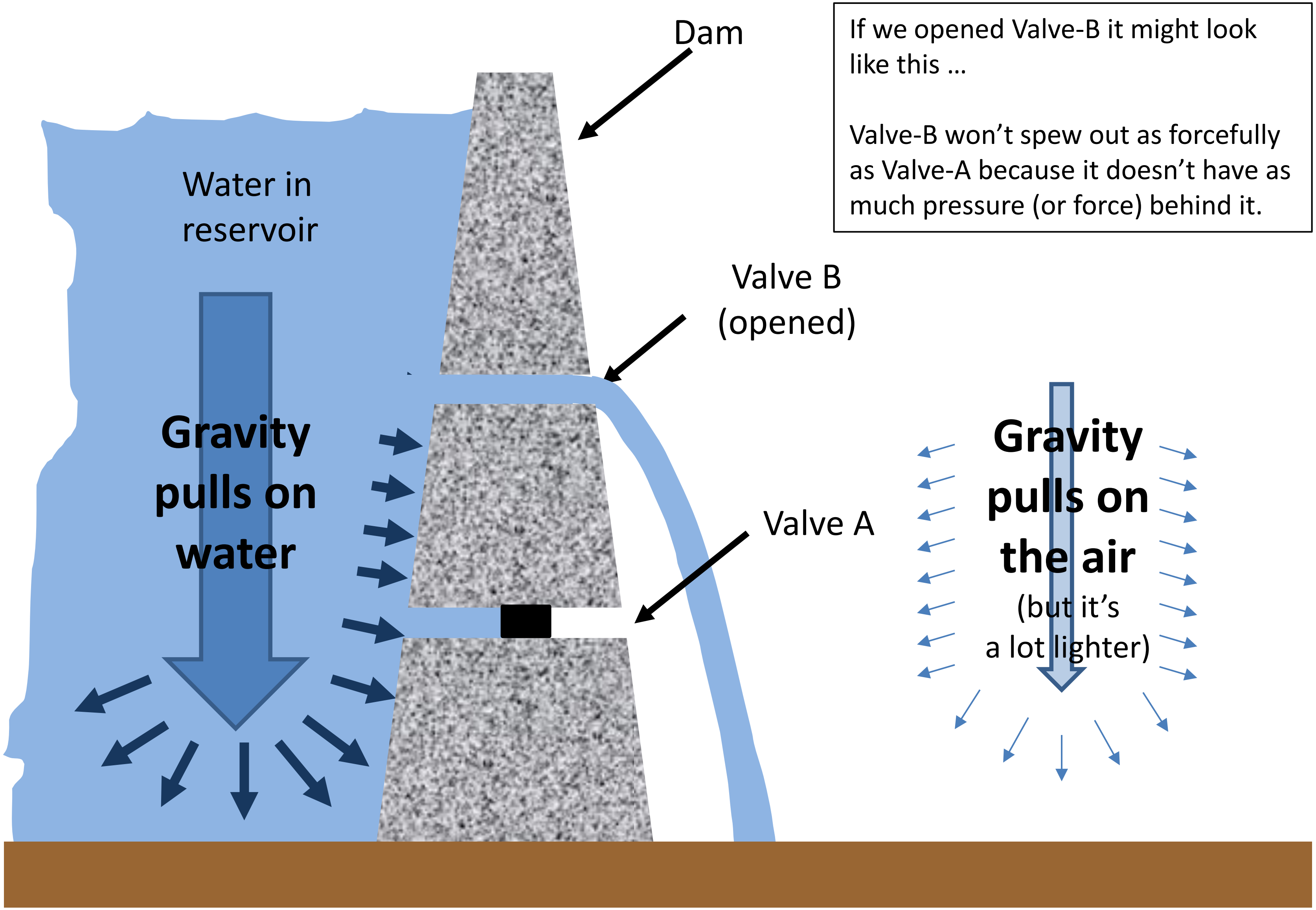


So if we opened Valve-A, it might look like this …



If we opened Valve-B it might look like this …

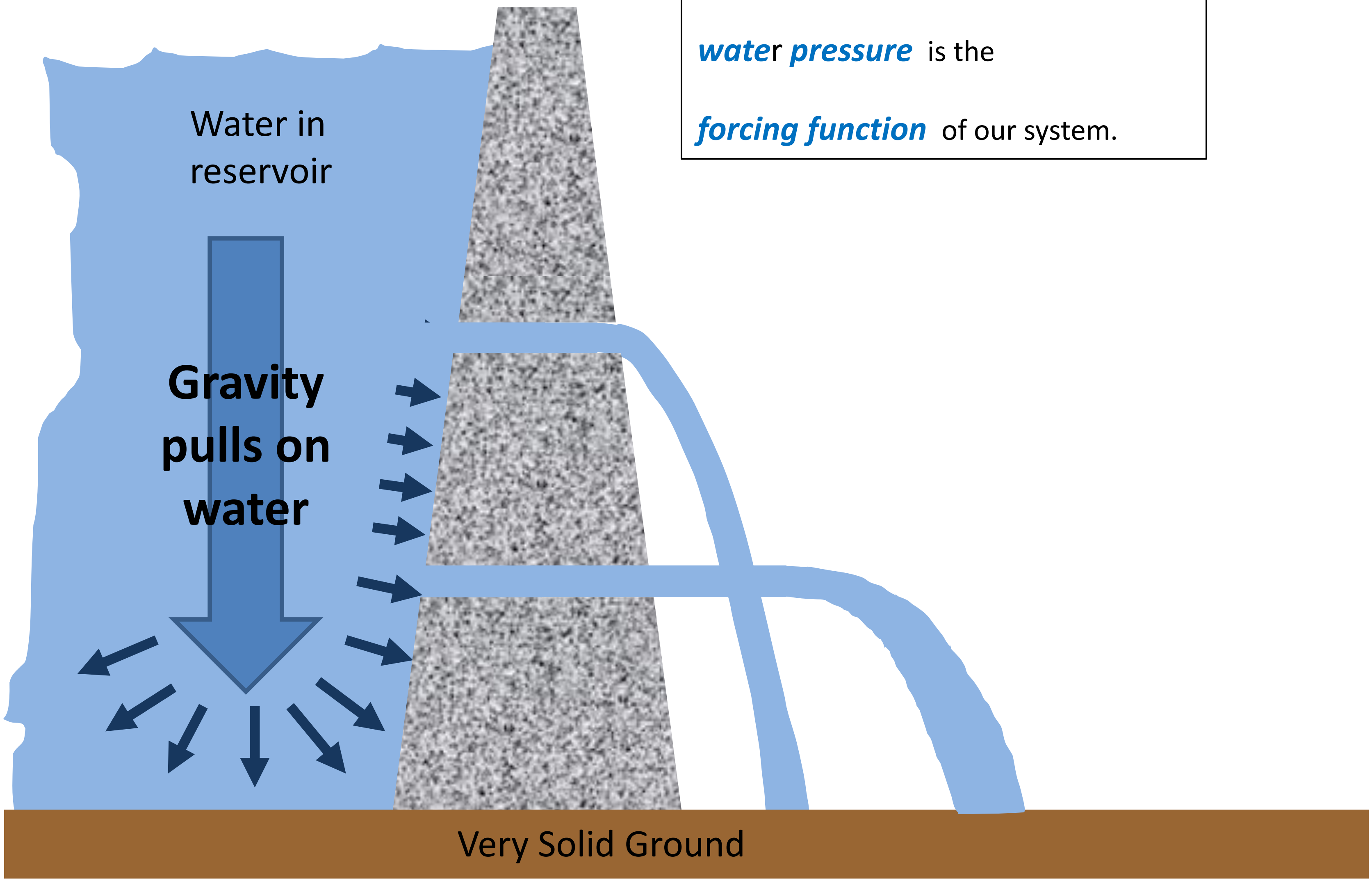
Valve-B won't spew out as forcefully as Valve-A because it doesn't have as much pressure (or force) behind it.



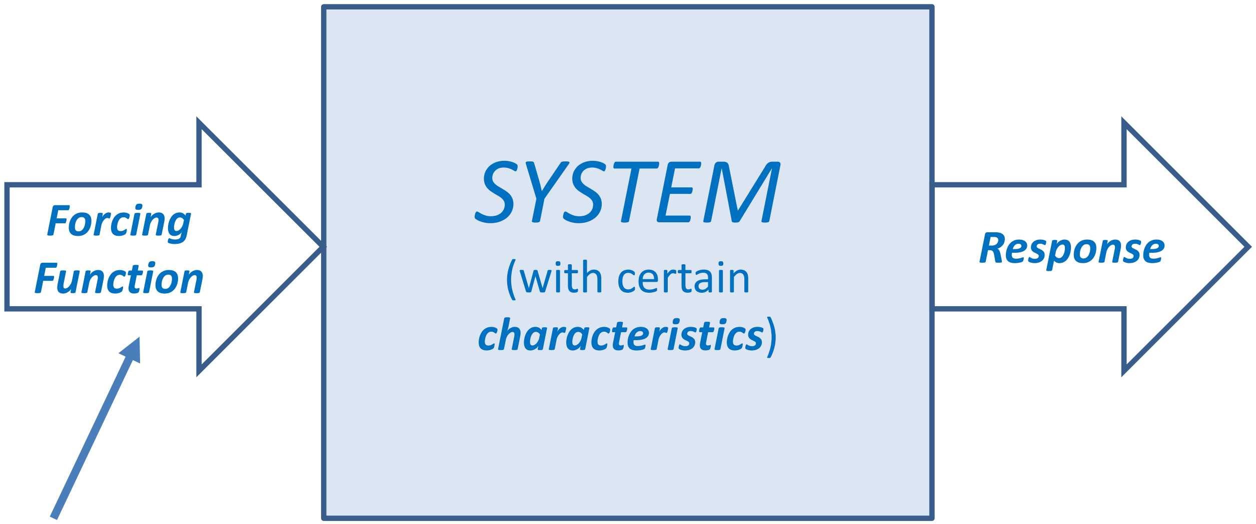
So, in this case .....

water r ***pressure*** is the

forcing function of our system.



Some Important System Vocabulary

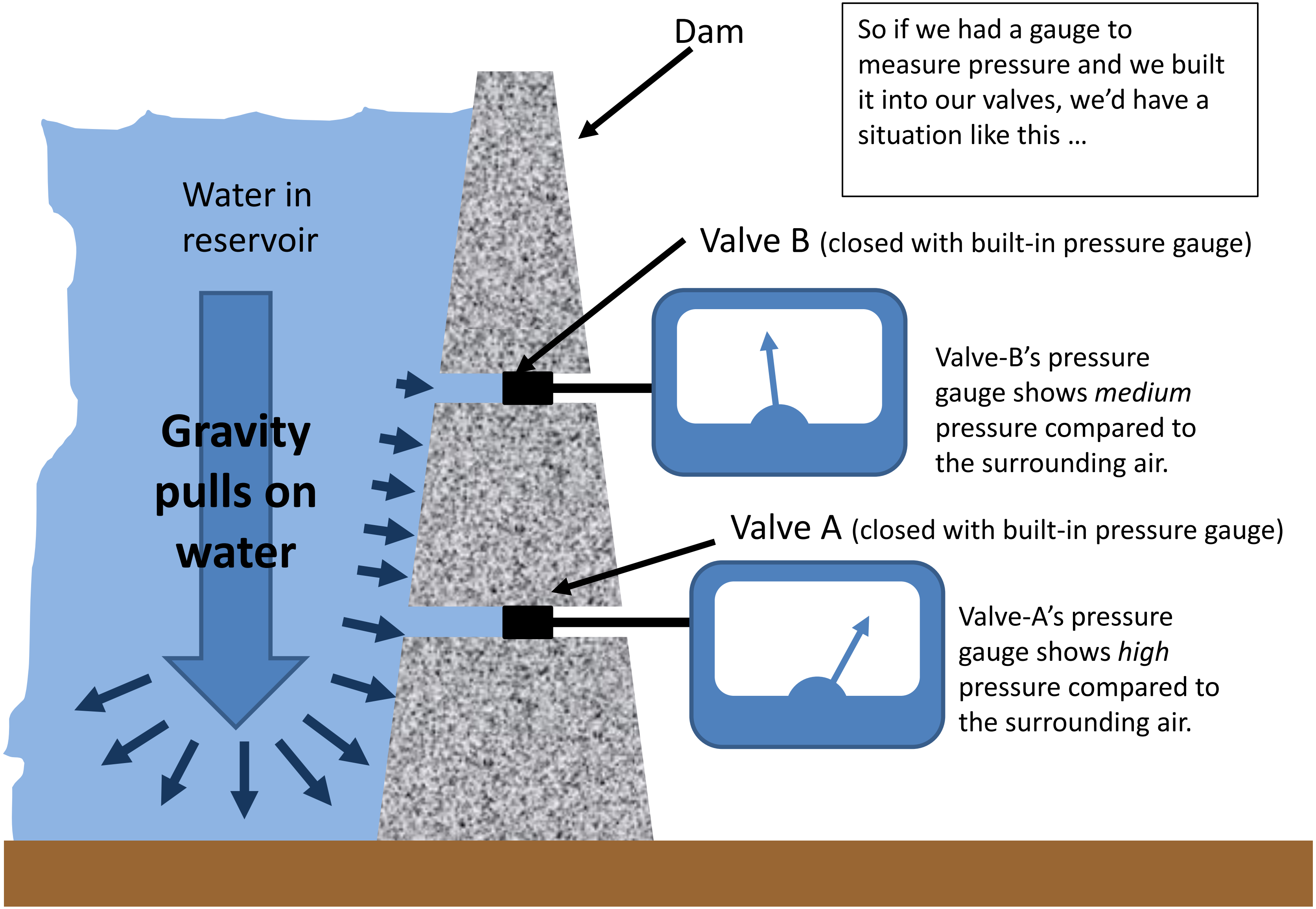


Also called:

Stimulus, or ***Excitation***

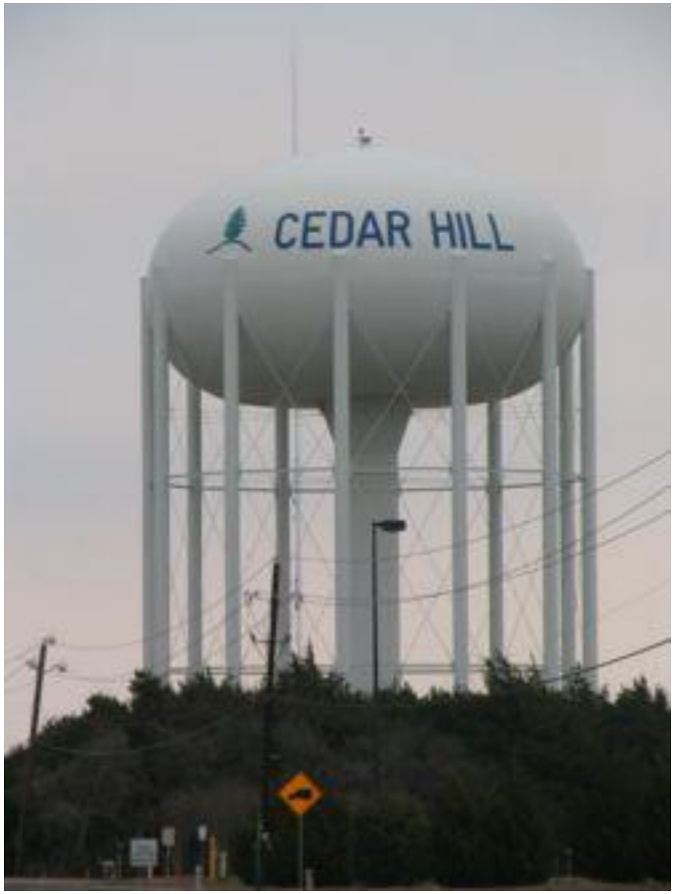
(In electronics we tend to use these last two terms)

So if we had a gauge to measure pressure and we built it into our valves, we'd have a situation like this …



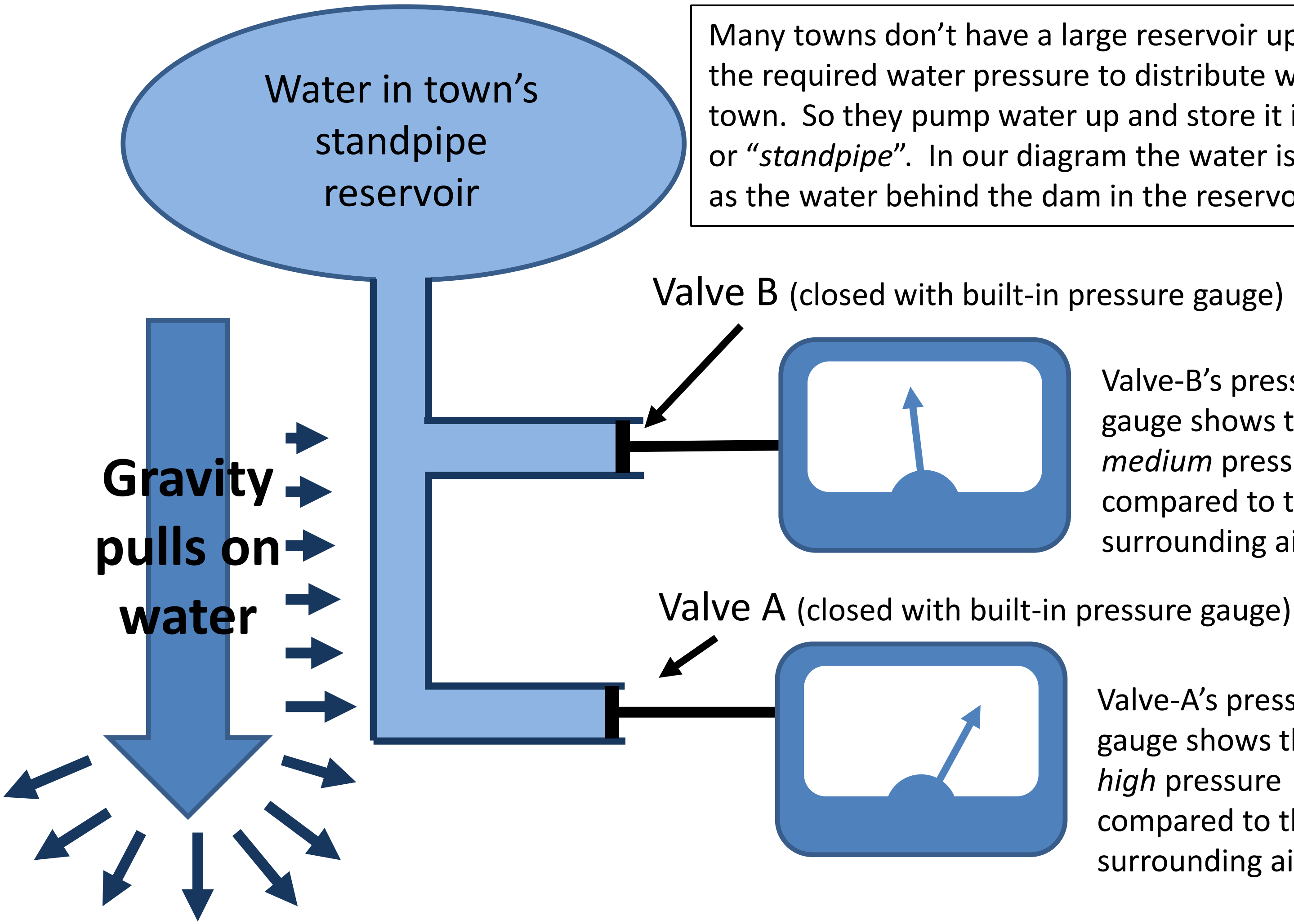
Ever seen one of these?

http://lindseyannestainer.blogspot.com/2010_10_01_archive.html



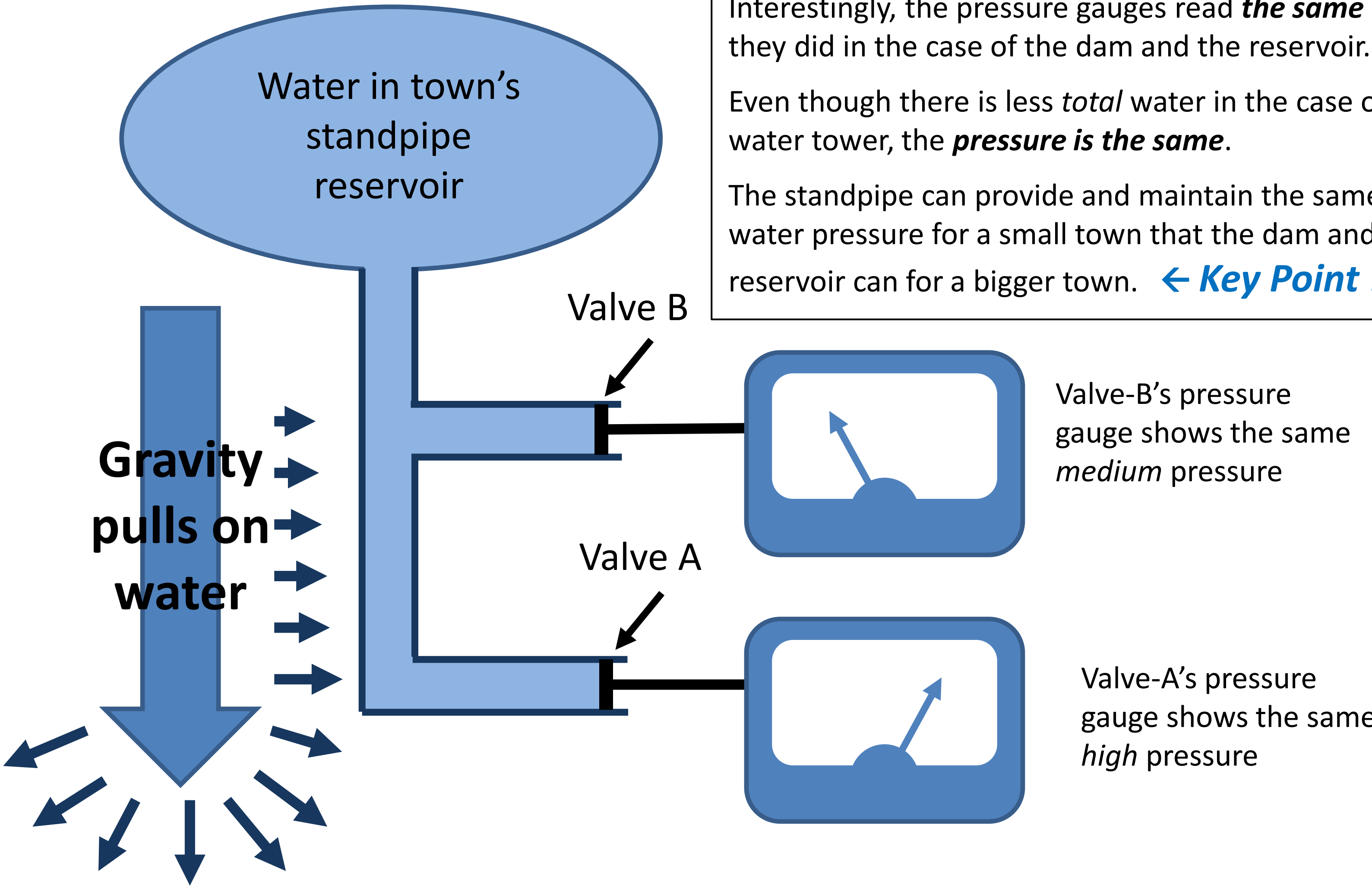
http://www.thepeoplehistory.com/watertowers/250px-CedarHillWaterTower20070127.jpg

Many towns don't have a large reservoir up high to generate the required water pressure to distribute water to the entire town. So they pump water up and store it in a "*water tower*" or "*standpipe*". In our diagram the water is at the same **same height** as the water behind the dam in the reservoir.



Valve-B's pressure gauge shows the *same medium* pressure compared to the surrounding air.

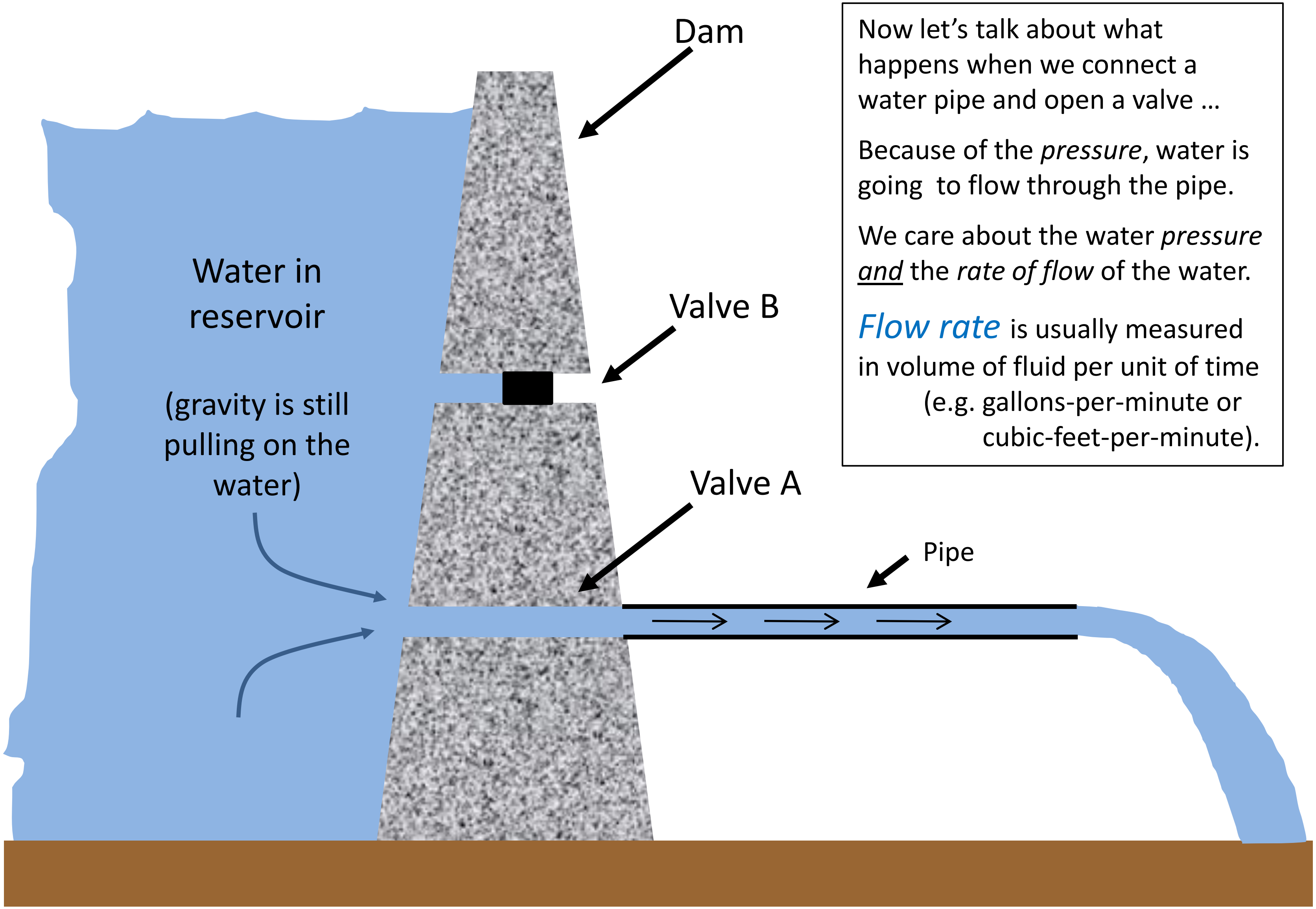
Valve-A's pressure gauge shows the *same high* pressure compared to the surrounding air.



Interestingly, the pressure gauges read ***the same*** as they did in the case of the dam and the reservoir.

Even though there is less *total* water in the case of the water tower, the ***pressure is the same***.

The standpipe can provide and maintain the same water pressure for a small town that the dam and reservoir can for a bigger town. ← ***Key Point !!!***



Now let's talk about what happens when we connect a water pipe and open a valve …

Because of the *pressure*, water is going to flow through the pipe.

We care about the water *pressure* *and* the *rate of flow* of the water.

Flow rate is usually measured in volume of fluid per unit of time (e.g. gallons-per-minute or cubic-feet-per-minute).

Some Important System Vocabulary

We’ve already seen how ***pressure*** is our system’s ***forcing function***.

We just learned about ***flow rate*** which is our system’s ***response.***

Questions:

1. In a given system, if we increase the *pressure*, what will happen to the *flow rate*?

2. Given two different systems with the SAME *pressure*:

    1. System #1 has LARGE diameter pipes (“fat pipes”).
    2. System #2 has SMALL diameter pipes (“skinny pipes”).
    3. Which system is likely to have the higher *flow rate*?

3. Would you say pipe diameter is a characteristic of the system?

Some Important System Vocabulary

We've already seen how *pressure* is our system's *forcing function*.

We just learned about *flow rate* which is our system's *response*.

Questions:

1. In a given system, if we increase the *pressure*, what will happen to the *flow rate*? Flow rate will increase

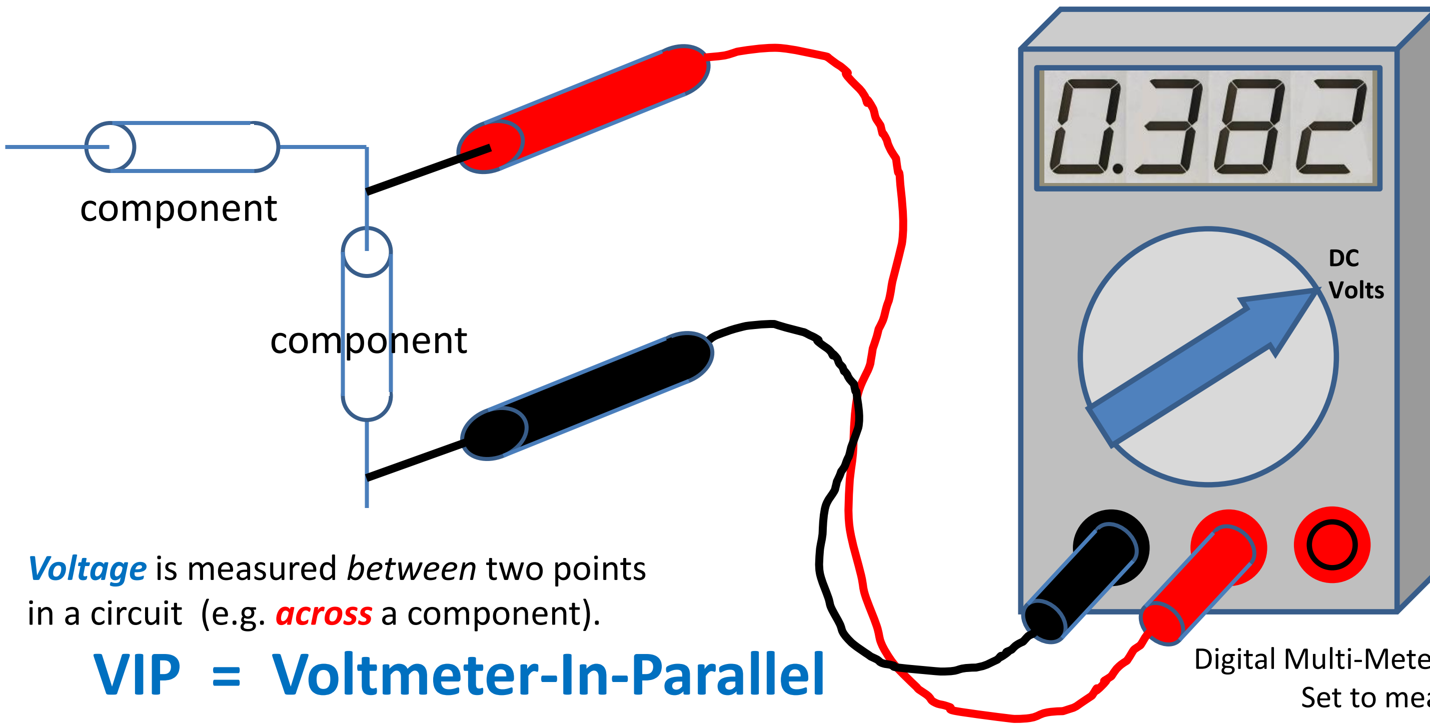
2. Given two different systems with the SAME *pressure*:

    1. System #1 has LARGE diameter pipes ("fat pipes").
    2. System #2 has SMALL diameter pipes ("skinny pipes").
    3. Which system is likely to have the higher *flow rate*? System #1

3. Would you say pipe diameter is a characteristic of the system? Yes.

Voltage can be thought of as "electrical pressure"

In electricity, we consider ***voltage*** to be analogous to water pressure. We'll measure *voltage difference* (also known as *potential difference*) using a *voltmeter* with two wires, called *probes*, to sense the electrical "pressure" difference between the two points of the circuit. ***For our studies we will consider voltage to be the forcing function of our example systems.*** The unit of electrical potential, and thus potential difference, is the ***Volt***, after Alessandro Volta who created what may be the very first chemical battery.



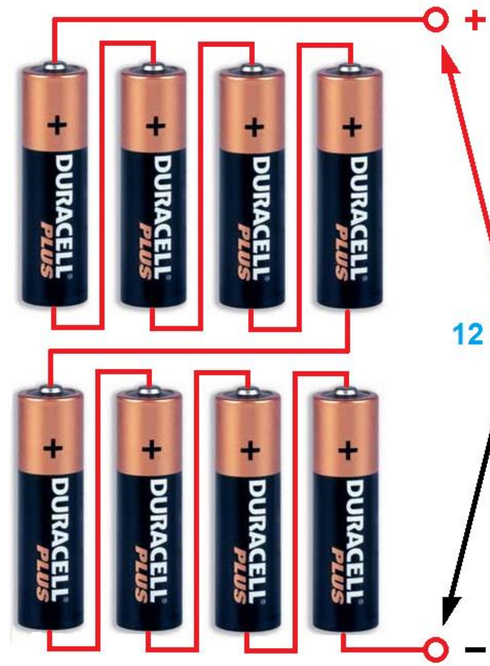
Voltage is measured *between* two points in a circuit (e.g. ***across*** a component).

VIP = Voltmeter-In-Parallel

Digital Multi-Meter ("DMM")
Set to measure ***Volts***

Voltage can be thought of as "electrical pressure"

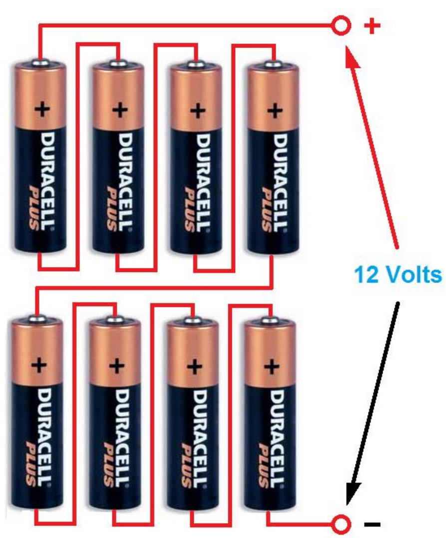
Remember the reservoir with the dam to store up water and create water ***pressure***? And do you recall (just a few slides back) that a water tower (also called a standpipe) can be used by a small town without a handy reservoir to create the same water ***pressure***? As long as the town with the standpipe doesn't use water too quickly and replenishes the water they do use, that town will always have sufficient water ***pressure***. Here's an electrical example:



An automobile battery will provide approximately 12V of electrical "pressure". But so will 8, 1.5V AA-Cells connected in "series" (8 x 1.5V = 12V).

But I can't start a car with will 8 AA-Cells! What gives?

The automobile battery can be thought as the reservoir with 12V of "*pressure*" and plenty of water flow available **at that stated pressure**.

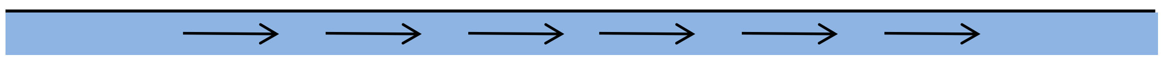


The 8 AA-Cells can be thought as the standpipe with the same 12V of "*pressure*" and enough water flow for a small town. But not enough for a big city. Trying to start a car would be like trying to supply enough water for a big city from a small town water tower. The water would quickly be drawn out and there would be little or no water pressure.

Flow Rate

Current can thought of as water flow rate

Water pressure forces water to go through the pipe at some *flow rate*. More pressure, more water per second, and thus a higher *flow rate*.



To achieve a given flow rate we need to apply some corresponding water pressure. To achieve a higher flow rate, we'll need more pressure. This gives rise to the idea that water flow is being opposed by friction in the pipe, the water's own viscosity, and any other means. These are *characteristics* of our system. In electricity a similar characteristic opposition-to-flow is called the "*resistance*" of the circuit.

Some Important System Vocabulary

Water System

Applied *water pressure* is the *forcing function*.

Water-to-pipe friction, water viscosity, etc. are considered *system characteristics*.

Water flow rate is the *response* of the system with given pipe characteristics to a given water pressure.

Electrical System

Applied *voltage* is the *forcing function*.

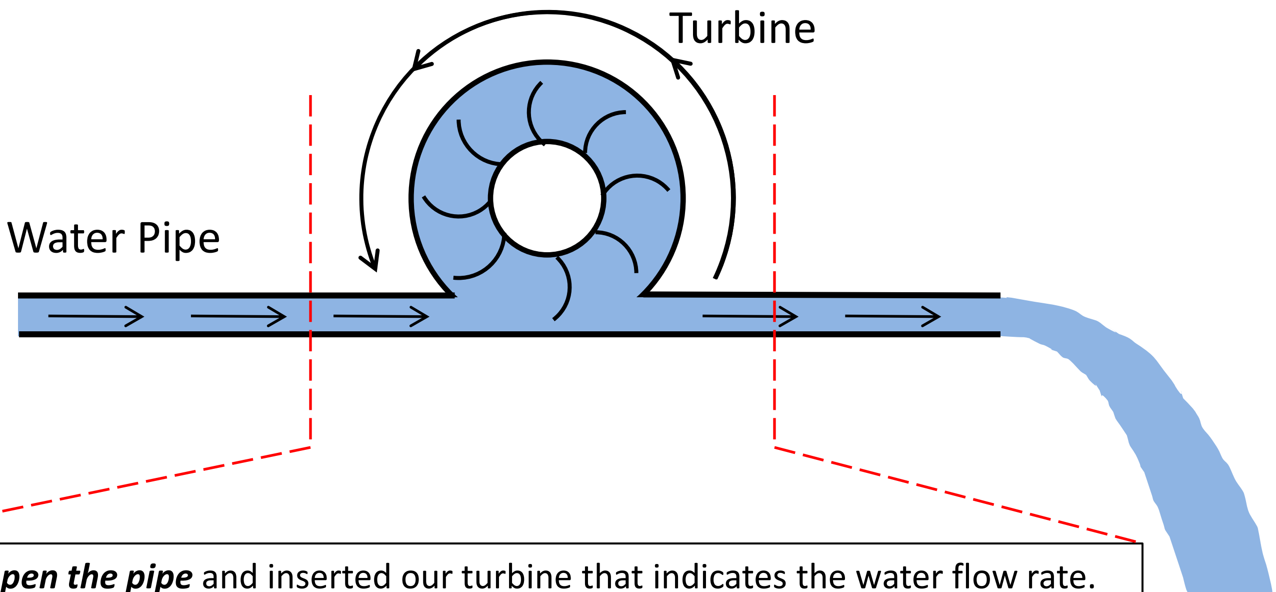
Electrical resistance is one of our *system characteristics* (there are others).

Electrical *current* is the *response* of the system with given characteristic resistance to a given applied voltage.

How do we measure *Flow Rate*?

By watching the speed (the revolution rate) of the spinning turbine below, we can determine the volume of water flowing past this point in the pipe per second (the ***flow rate***). This is very much like the speedometer or tachometer in an automobile.

Notice that we had to "***break into the flow***" to measure the flow rate. That is, we had to ***cut open the pipe*** and insert our turbine operated flow meter.



We ***cut open the pipe*** and inserted our turbine that indicates the water flow rate.
Faster turbine speed indicates higher water flow rate.
Slower turbine speed indicates lower water flow rate.

Examples of Commercial Fluid Flow Meters

http://dir.indiamart.com/chennai/mass-flow-meters.html

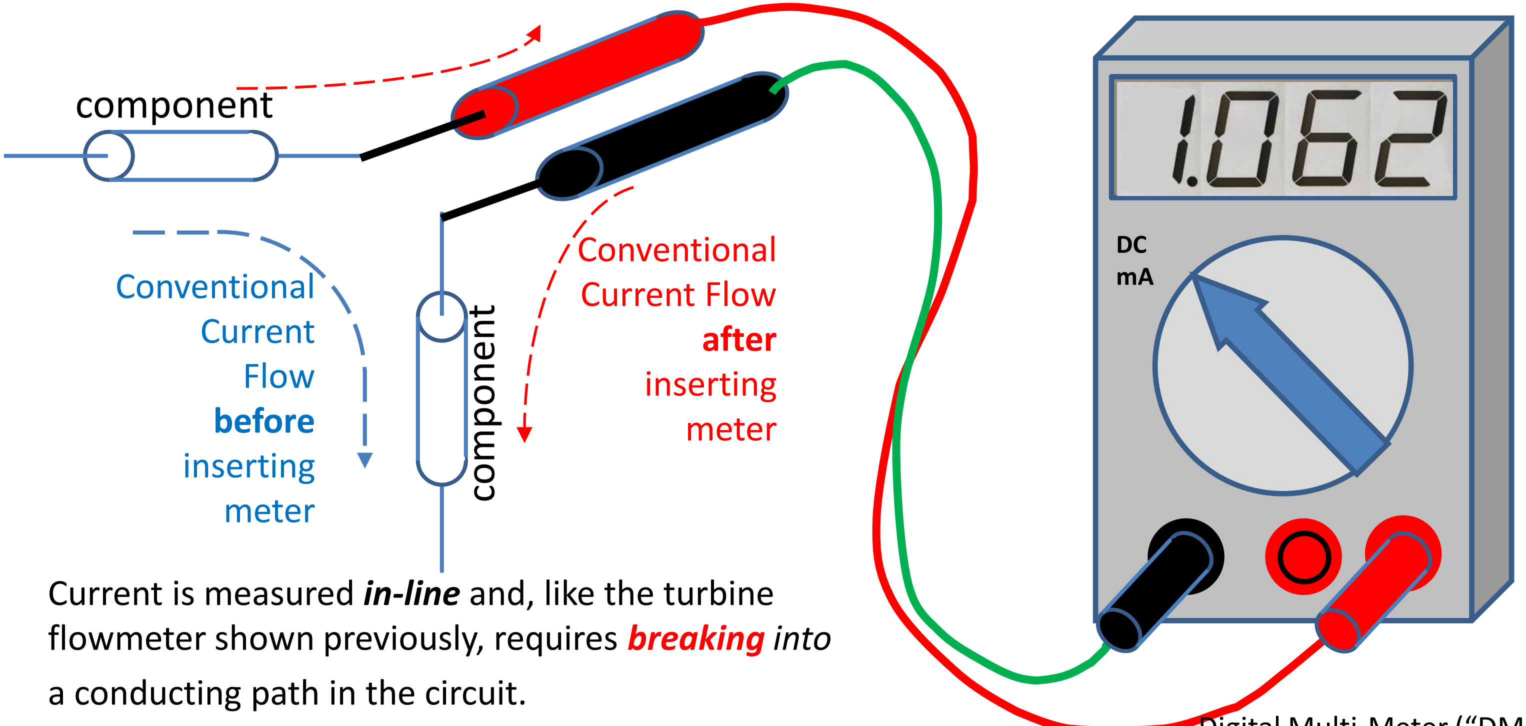
https://upload.wikimedia.org/wikipedia/en/e/ee/Water_meter.jpg

http://www.northerntool.com/shop/tools/product_200514320_200514320

Notice how they are all designed to be ***cut into the pipe***?

Current can be thought of as "electrical flow rate"

We consider ***electrical current*** to be analogous to water ***flow rate***. We'll measure current using an *ammeter* interrupting the circuit with two wires, called *probes*, to sense the electrical flow rate through a particular path of the circuit. The electrical unit of current flow is the ***Ampere***, after André-Marie Ampère, an important mathematical physicist involved with the discovery of electromagnetics. We often shorten Amperes to "***Amps***" and we denote it as "***A***".



Current is measured ***in-line*** and, like the turbine flowmeter shown previously, requires ***breaking*** *into* a conducting path in the circuit.

Digital Multi-Meter ("DMM")
Set to measure milliAmperes
(thousandths of an Ampere)

ABC = Ammeter-Breaks-the-Circuit

Concepts and Vocabulary Review for Unit-01

In this section we described the following:

1. How basic electricity is similar to basic water flow.
2. The electrical quantities *Voltage*, *Current*, and *Resistance*.
3. Of *Voltage*, *Current*, and *Resistance*:
   1. *Voltage* is the *forcing function* that drives our electrical systems.
   2. *Resistance* is a *characteristic of the electrical systems* we study.
   3. *Current* is the *response* of a given system to a given applied *Voltage*.
4. Digital Multi-Meters are used for the most common electrical measurements.
5. The measurement of *Voltage* and *Current* quantities using a "*DMM*":
   1. Voltage is measured ***across*** two points (or in *parallel*; remember ***VIP***).
   2. Current is measured ***through*** a path so you have to ***break*** the circuit (remember ***ABC***)

The End