Electricity/Water Analogy

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One way to visualize the effects of electricity is to use a water analogy. In fact, the term electrical current is used since it is analogous to water current.

In our water system, we should imagine a system of pipes with pumps, valves and other elements that control the flow of water. These pipes and all elements in the water system should be full with water and not contain any air in the system.

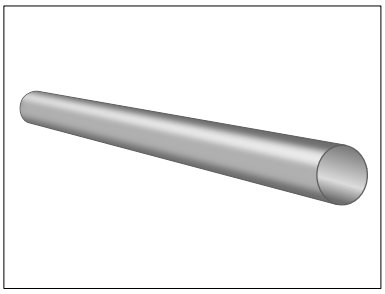
In this system, we have the following basic analogies...

1) Voltage potential ⇔ Water pressure
2) Current flow ⇔ Water flow
3) Electrons ⇔ Water molecules
4) Wire ⇔ Water pipe
5) Switch ⇔ Water valve
6) Resistor ⇔ Water pipe with restriction
7) Capacitor ⇔ Water tank with flexible membrane
8) Inductor ⇔ Water tank with heavy paddle wheel
9) Current source ⇔ Water pump
10) Voltage source ⇔ Water pump with feedback

Some more details on these analogies are described below.

Wire

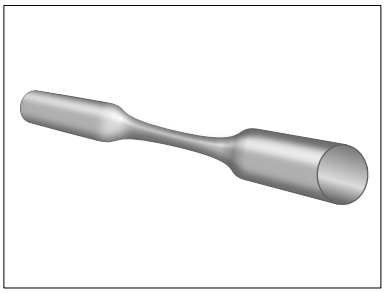
A wire is equivalent to a large diameter pipe as shown below.



A large pipe is mentioned above since an electrical wire has near zero resistance and therefore will have large current flow if the voltage difference from one of the wire to the other is not zero.

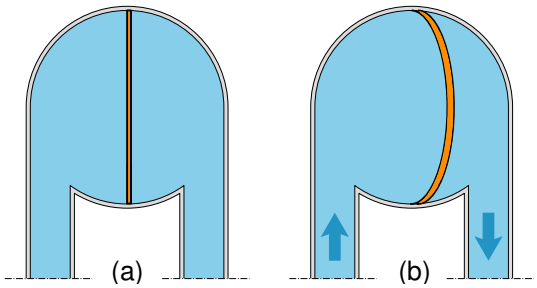
Resistor

A resistor is equivalent to a restricted diameter pipe as shown below



Capacitor

A capacitor is equivalent to a water tank that has a flexible membrane between the 2 pipes into the tank as shown below.

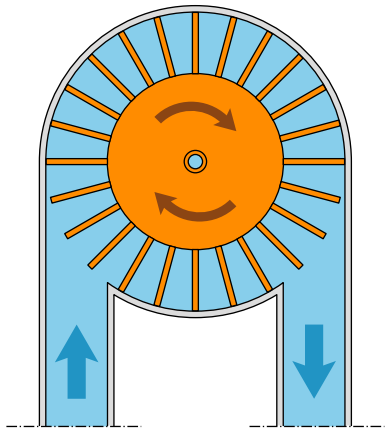


In the above figure, (a) shows the case where there is no water flow into the tank and the flexible membrane is not stretched in either direction. In (a), the water pressure difference between the 2 sides of the membrane is zero. In (b), water is flowing into the tank on the left side and out of the tank on the right side. As a result, the flexible membrane is stretched towards the right. In (b), the left side has a higher water pressure than the right side. If a switch stopped the water flow on either side of the water tank, the flexible membrane would remain where it is and the water pressure difference would remain the same between the 2 sides of the tank.

If the water flow was in the other direction, then the flexible membrane would expand towards the left side.

Inductor

An inductor is equivalent to a water tank that has a heavy paddle wheel between the 2 pipes into the tank as shown below.



The weight of the paddle wheel determines how quickly the paddle wheel will spin once a water pressure difference is applied to the paddle wheel tank. The rate of spin of the paddle wheel determines the water flow. So the analogy for an inductor is like the moment of inertial for the paddle wheel. It can not start or stop instantaneously but takes some time to build up or slow down. A heavier paddle wheel is equivalent to a larger inductor.

Current source

A current source is equivalent to a water pump that sets the water flow rate to a constant value

Voltage source

A voltage source is equivalent to a water pump with feedback. The feedback is required around the pump such that a fixed pressure is across the water pump. If the pressure is too low, the feedback will cause the pump to increase flow, and if the pressure is too high, the pump will reduce its flow. We should imagine that this feedback loop is so fast that all we see is a fixed pressure across the water pump.

KCL and KVL

Kirchoff's current and voltage laws both work well in our water system.

The pressure around any loop of water elements must always equal zero.

The total water flow into any node of at water system must equal zero. A node in our water system might be a T-joint water connection. A T-joint would be a 3 input node.

Acknowledgement

The above figures are taken from https://en.wikipedia.org/wiki/Hydraulic_analogy and some were modified for clarity.