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IMGD 3100 – Novel Interfaces for Interactive Environments: Electricity

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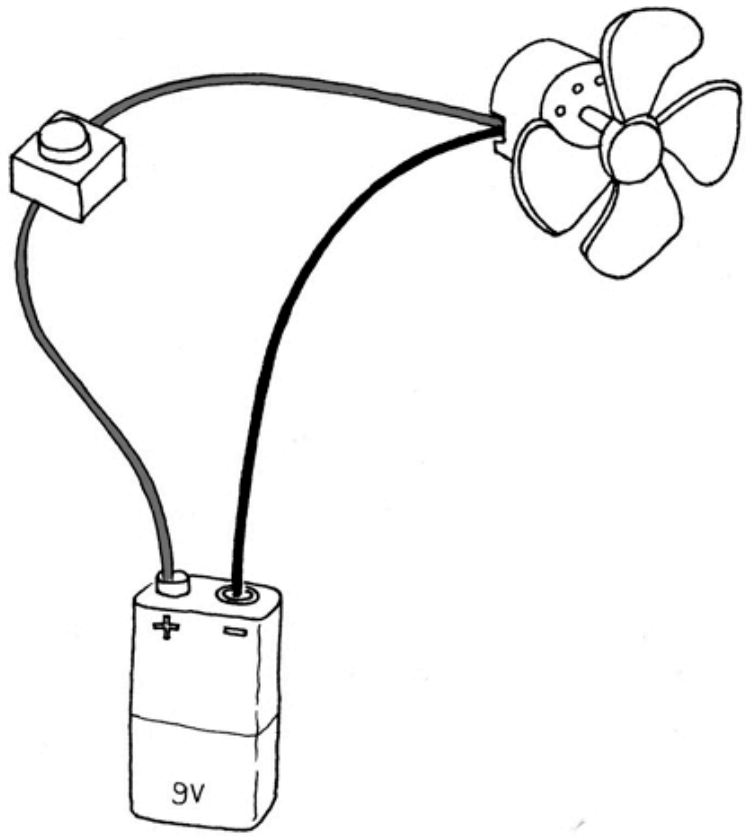
Overview

- So you've built some circuits, made some stuff blink, read values from devices, etc.
- Do you understand a little better what's going on with all this ECE stuff?
- Since almost none of you have any ECE background, how can I expect you to do this stuff?!?!??!
- Let's see what we know…

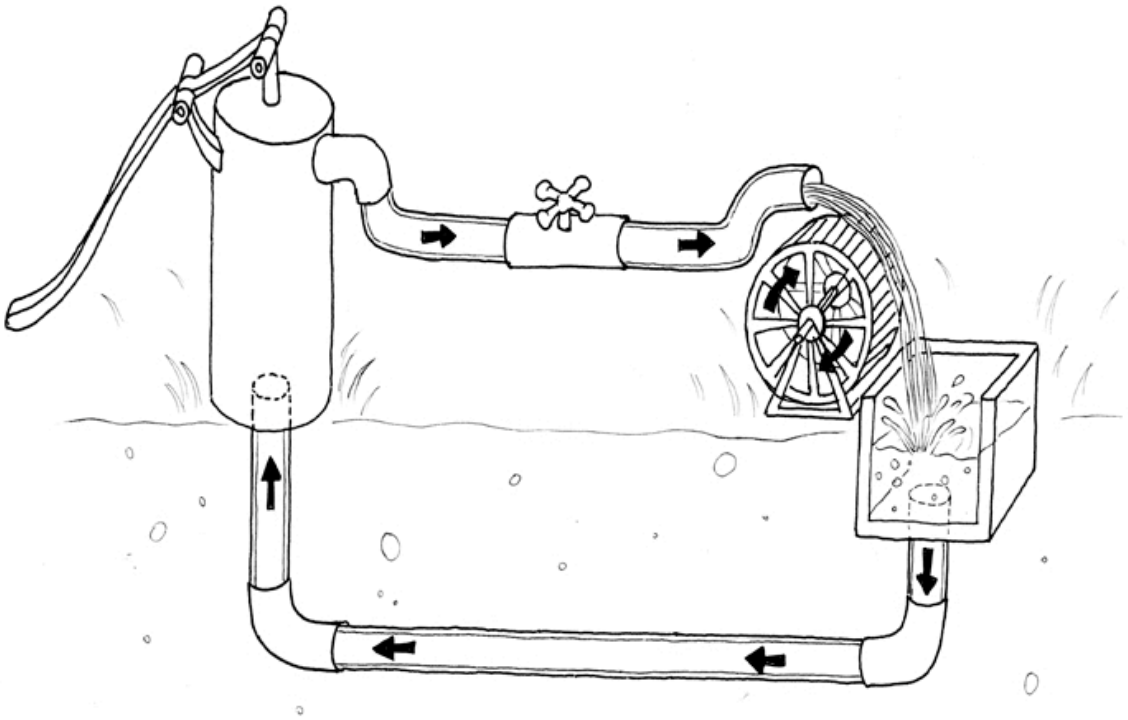
Simple Current Flow

- Parts of the system
  - Power source
  - Output device
    - Motor
  - Switch
  - Conduits
- What if you switch the ***polarity***?



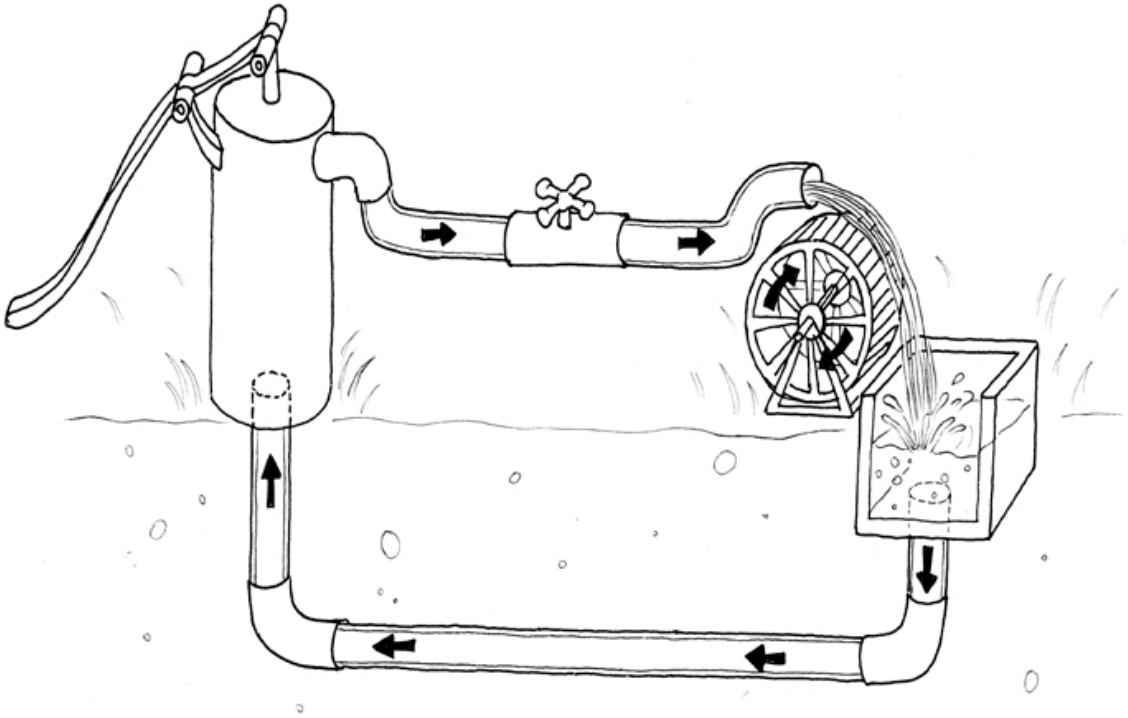
Water Analogy

- Water source and pump
  - Battery
- Tap
  - Switch
- Water wheel
  - Motor
- Open tap, water drives the wheel



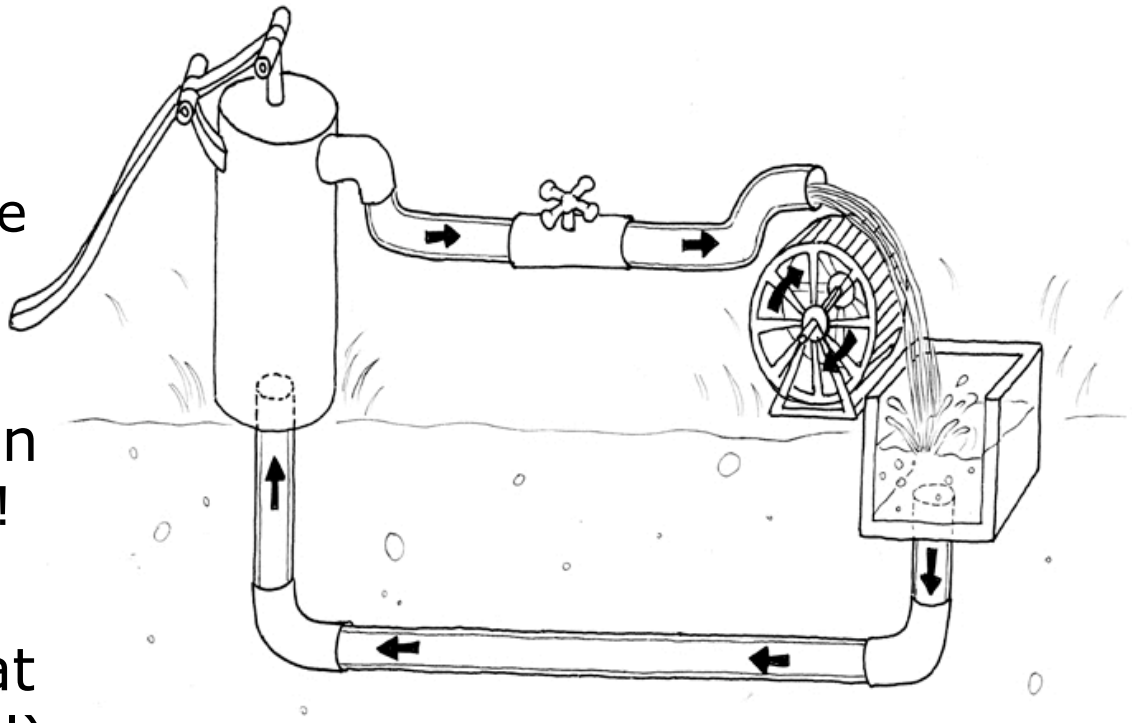
Water Analogy: Important Points

- Two factors
  - Water Pressure
  - Flow rate
- Governed by
  - the power of the pump
  - Size of the pipe/ friction of wheel
- Larger pipe + stronger pressure = faster spin



Water Analogy: More Detail

- Larger pipes = less resistance
  - After some point, need more pressure to fill the pipe
- At some point, the wheel will breakdown
  - too much pressure!
- Some of the energy will come out as heat (from the wheel axel) or something else
  - Same in ECE



Making the Connection to ECE

- Pressure is produced by the pump
- Resistance produced by pipes
- Resistance produced by wheel
- The flow rate (e.g., liters/second)
- In ECE:
  - Power source (battery, wall wart) is the pump
  - Wires, resistors, etc. are the pipes
  - Devices are the wheel
  - Current is the flow rate

Arduino Programming

- We know that

  digitalWrite(13, HIGH);

  will turn on the LED attached to pin 13
- But what does this *mean*?
- It means the pin will be driven with 5 volts.
  - What is a *Volt*?

Voltage

- Voltage is related to potential energy
- Recall:
  - if you lift something off the ground, it gains potential energy
  - If you let go, it releases the potential energy stored when you lifted it.
- Assume you have a positive charge and a negative charge
- They are attracted to each other, and if you pull them apart, your effort is stored as potential energy

Voltage (cont.)

- If you release them, the charges jump back together (like the weight)
- For the weight, potential energy is calculated by plugging the height into:

  E=mgh (mass x gravity x height)

- For charges, height is analogous to voltage
- For the potential energy, you multiply the voltage times the charge you are raising
  - The "electronic height" of a charge

Voltage (cont.)

- So, what if, while the weight is being held up, someone puts a table underneath it?
  - Does the potential change?
  - How do you explain this?
- Potential is always measured between two points
  - It is an ***across*** variable.
- Same for voltage
  - Ground is one of the points by default

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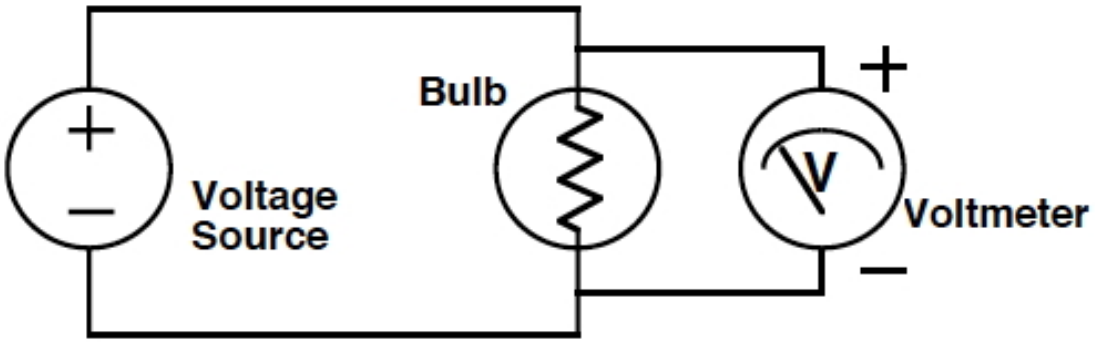
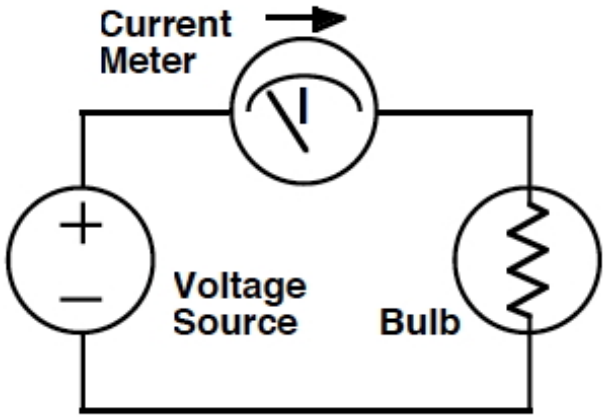
Current

- So, circuits provide paths for charges that have been raised to some potential to flow back down to ground
- This *flow of charge* is called Current
- Current is a ***through*** variable
- It is the first derivative of charge
  - The number of Coulombs of charge that pass a point per second
  - A *Coulomb* is about 6 x 10^{18} electrons

Voltage & Current

- Voltage is measured using a voltmeter
- Current is measured using a current meter (a.k.a. an *ammeter*)





- Direction (polarity) is important too!

Voltage & Current (cont.)

- Kirchhoff's Voltage Law (KVL)
  - The voltage that you drop on one side of a circuit must be equal to the amount of voltage you raised on the other side.
  - You can only fall the height you were raised
- Kirchhoff 's Current Law (KCL)
  - Current is a conserved quantity
  - If some amount of current flows into a part of a circuit, the exact same amount must flow out.

Making the Connection to ECE

- A 9V battery is a pump (9V of pressure)
  - Unit is ***Volts (V)*** named after the inventor of the battery
- Flow rate is called ***current***, and is measured in amperes or ***Amps (A)***
  - After André-Marie Ampère
- Higher voltage (pressure) lets you spin the wheel faster
- Higher flow rate (current) lets you spin a larger wheel

Making the Connection to ECE

- Resistance opposing the flow of current over any path is called ***resistance***, and is measured in ***Ohms (Ω)***
  - After German physicist Georg Ohm
- This guy also gave us an important law
  - ***Ohm's Law*** describes the relationship between current, voltage, and resistance.
  - The ***resistance*** in a circuit will determine the amount of ***current*** that will flow through it, given a certain ***voltage*** supply.

Ohm's Law

- If we measure the current from a 9V battery plugged into a simple circuit, the current will drop if we add more resistance.
- Formally stated:

  R (resistance) = V (voltage) / I (current)

  V = R * I

  I = V / R
- Why "I" for current?

Watts (W)

- Rate of energy conversion
- Work is done at a rate of one watt when one ampere flows through a potential difference of one volt

  1W = 1V * 1A
- A 100 W bulb burning for 1 hour would consume 100 watt-hours (W-h)
- A 40 W bulb could burn for 2.5 hours and consume the same energy (100 W-h)

More Terms

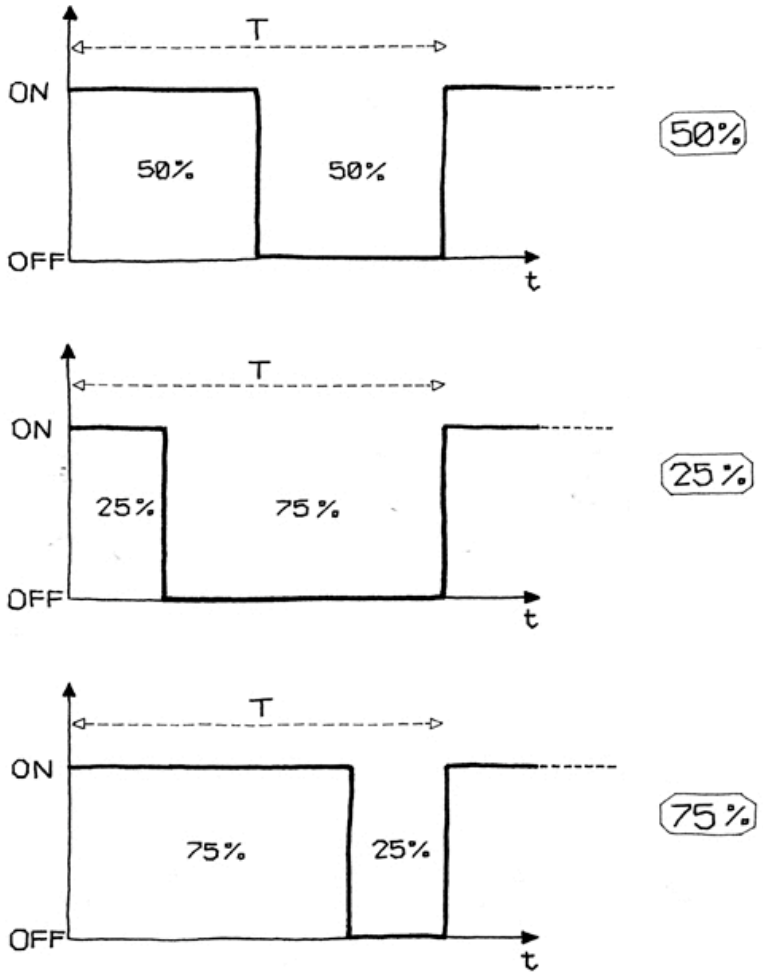
- Capacitance
  - The ability for a body to hold a charge
  - Used for
    - Temporary power storage (UPS, laptops)
    - Smoothing a power signal
- Transistor
  - Solid-state electronic switch
- MOSFET
  - Metal–Oxide–Semiconductor Field-Effect Transistor
  - When a Voltage is present on a specific pin, current flows between the other two pins
  - Used to amplify or switch electronic signals
- Relay
  - Electrically operated switch
  - Current creates a magnetic field which "throws" the switch

Varying the Output

- We've seen how easy it is to turn things ON and OFF
  - But this quickly becomes too limiting!
- Given Ohm's Law, how can we change the brightness of an LED?
  - Increase the resistance
    - Maybe with a resistor ladder
- How else?
  - Quickly blink it ON and OFF

Pulse-Width Modulation (PWM)

- Vary the percentage of time over a given period that an output is HIGH (or LOW)
  - This is how traditional dimmer switches work
- Period
  - Total time for the signal
- Duty Cycle
  - Percentage of the period the signal is HIGH



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Persistence of Vision

- Human eye won't notice down to a certain point
  - http://hackedgadgets.com/2008/11/05/arduino-rotating-led-display/

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Further Reading

- http://antonine-education.co.uk/electronics_as.htm