IMGD 3xxx - HCI for Real, Virtual, and Teleoperated Environments:

Electricity

by

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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 are the pipes
- Devices are the wheel
- Current is the flow rate
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 I measure the current from a 9V battery plugged into a simple circuit, the current will drop if I add more resistance.
- Formally stated:
  
  \[ R \text{ (resistance)} = \frac{V \text{ (voltage)}}{I \text{ (current)}} \]
  
  \[ V = R \times I \]
  
  \[ I = \frac{V}{R} \]
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

\[ 1W = 1V \times 1A \]

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

- Human eye won't notice down to a certain point
Further Reading

- [http://antonine-education.co.uk/electronics_as.htm](http://antonine-education.co.uk/electronics_as.htm)