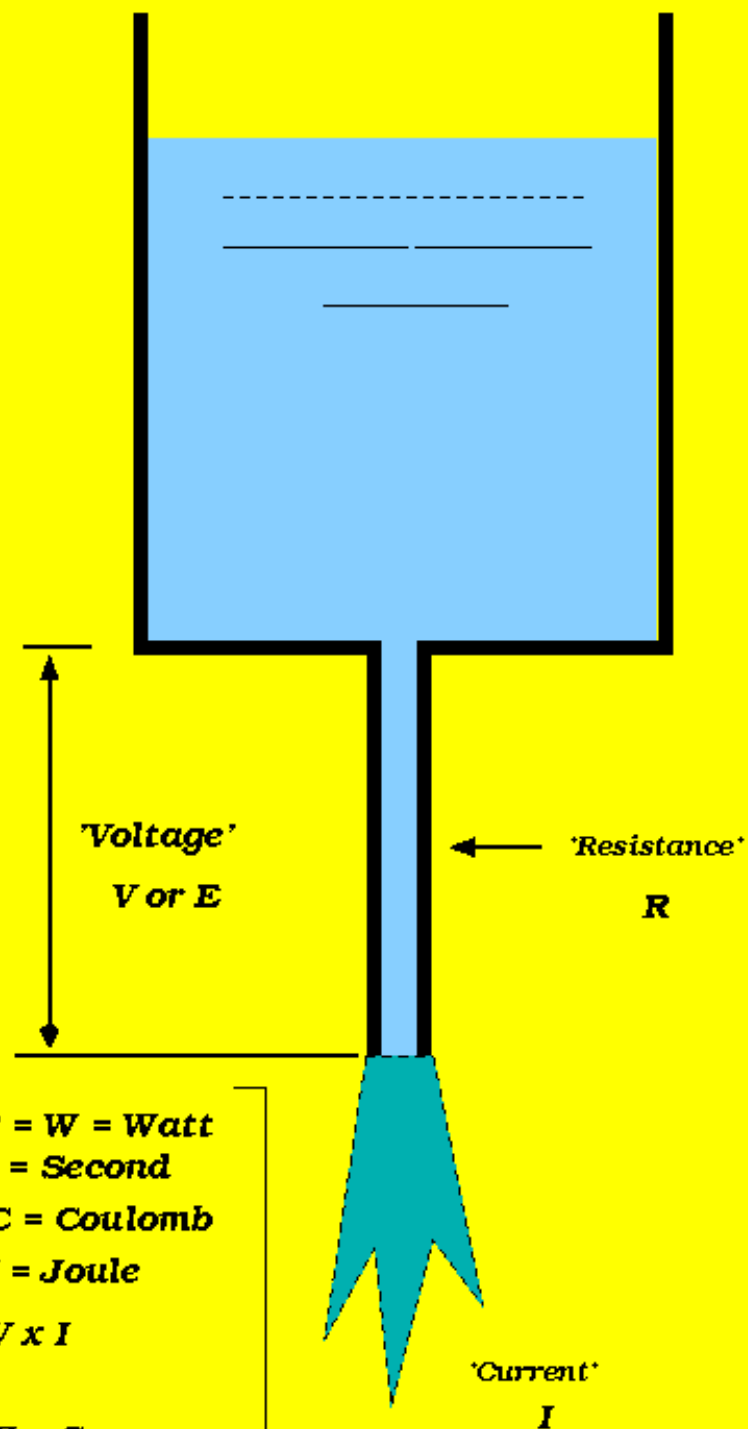


Intro to Transistors

- NOTE: 4/8/2017: Everything but these slides ready for review and detail corrections
- Orientation and Scope of this session
 - Conventional current flow notations used everywhere
 - Functional, functional, functional
 - References to theory but stressing application
 - A few simple device types and a few use cases
- Starting from Square One: Electricity and Ohm's Law
 - Water Analogy
 - Resistor combination equations and exercises
- Bipolar transistor operation
 - Hands on Exercises
- N Channel (logic level) Field Effect transistor operation
 - Exercises

Measuring volts easy: amps harder

- We'll measure voltage in our circuits for three reasons:
 - The digital meter reading voltage usually won't interfere with the circuit. Measuring current can affect circuit operation due to "burden voltage" (the small, but sometimes significant voltage drop used to measure the current)
 - Have to swap leads with most meters
 - Forgetting to swap back can blow a fuse



$I = V / R$	$P = W = \text{Watt}$
$R = I / V$	$s = \text{Second}$
$V = IR$	$C = \text{Coulomb}$
	$J = \text{Joule}$
$P = W = V \times I$	
$C = I \times s$	
$J = C \times V = W \times S$	

Combining Resistors

Rules for combining resistors

$$R_{\text{total_in_series}} = R_1 + R_2 + R_3$$

In terms of the analogy, 100 feet of pipe offers 100 times the resistance of one foot.

$$R_{\text{total_in_parallel}} = 1 / (1/R_1 + 1/R_2 + 1/R_3)$$

In terms of the analogy, two pipes of equal bore size offer ½ the resistance of one.

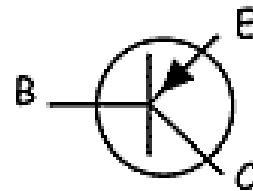
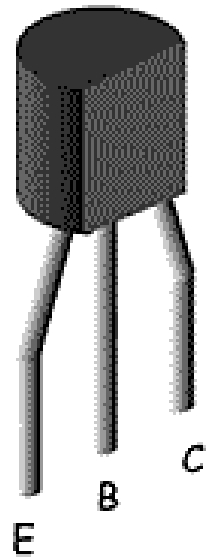
(Complete exercise handout)

Junction Transistors

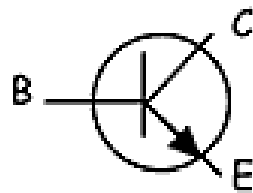
- Three terminals: Emitter, Base, Collector
- Many sizes and characteristics
- All share this behavior:
 - In normal operation relatively small changes of current flow through the base control larger current flow through the emitter and collector
 - See figure 4.51 on page 436 of Practical Electronics for Inventors, Scherz and Monk, 3rd edition, 2013. (A copy will be passed around at the session)

Physical vs Schematic

TO-92 (Plastic)



PNP Like 2N3906



NPN Like 2N3904

Operation: NPN Details

- (“Simple Common Emitter” simulation with <http://everycircuit.com>)

Exercise 1: Duplicate the simulation

- Boards set up for first common emitter circuit
- Leave batteries disconnected when changing anything or not exercising circuit
- (Exercise to measure a resistor with the meter)
- (Exercise to measure battery voltage)
- Measure circuit behavior while R1 trim pot (potentiometer – variable resistor) turned between stops.
- Make a table of base and collector voltages

$$\text{Amps} = \text{Volts} / \text{Ohms}$$

- Measure voltage from one end to the other of the 10k (10,000 aka “brown black orange”) resistor
- While doing this, adjust the potentiometer
- How does the current through the resistor change?
- Over and over with electronics: having two of the three values for variables of Ohm’s Law reveals the third value.

But it doesn't DO anything!

- (Getting to Blinky CE simulation 1)
- (Add LED)

LED not doing anything!

- What could be wrong?
- How much current does the LED require to light? More than 40-odd microamperes!
 - Typical LEDs like this work well with 1-20 milliamperes
- How to get more current?
- Fix the collector resistor
 - LED drops two volts, so resistor drops three (transistor resistance ignored)
 - 5 milliamperes = three volts / 600 ohms (510 close enough)
 - Replace 10k resistor with “green brown brown” 510 ohm resistor

LED Still Not ON???

- What's happening with the LED?
 - Figure out current through LED
- Why isn't there enough current through the LED?
- Transistor gain is 100: To get 5 mA “out”, how much current has to go “in” transistor?
- Adjust base resistor
- Readjust trim pot as needed

Another amplifier: Common Collector

- Non-inverting
- When switched on, the emitter voltage is just a few tenths (“one diode drop”) lower than the base voltage.
- (Assemble common collector circuit)

FET Transistor

- Switches current, but switching mechanism basically different
- Rough correspondence of three terminals:
 - Gate similar in function to junction transistor Base
 - Source similar to Emitter (with N-channel and “conventional flow” the current “comes out here”)
 - Drain similar to Collector
- A key point is that the gate part of the transistor is like a capacitor (which we’d have ideally covered, but “next time”). Turning the gate on is effectively charging up a capacitor, but once it’s charged the current needed to keep the transistor on is VERY SMALL
- But this also means the gate can be turned on accidentally with virtually no current

FET Circuit: running a motor

- Add FET, gate resistor, motor, rearrange
- Test to see that the gate is switched above a couple volts
- Double check rectifier diode: this prevents possible ***destruction*** of the FET transistor
- Connect big battery