ECE 2200/10 Introduction to Electrical Engineering for non-majors

A. Stolp
12/30/11
8/24/15,
8/21/23

2200 = 1/2 semester (Mining, Mat. Sci.)

ECE 2200 Without the Physics is hard, Plan on it!

2200, Decide today when you want to take the **final**:
Final is **after** official end of class unless you ask for different accommodation today.

2210 = Full semester (Mechanical, Chemical, etc.)

2210 Final Friday, Dec. 15, 8:00am

Make sure you are registered for the right class (2200 or 2210) and that you have the right syllabus.

BOTH

Regularly check the calendar on for this class on Canvas. Watch your Canvas announcements.
Be prepared to download and possibly print weekly packets, which include notes and homeworks.

Homeworks are due by 11:59 pm of the due date on Canvas. Make sure you have a way to scan paper or do your work on a tablet so that you will can submit a .pdf file. If the homework assignment .pdf provides room for you to work out the problem, please do your work on the provided .pdf files. This makes graders job easier.

WARNING: HWs are often due on non-class days.

Most labs start next week. Need a lab notebook and a U-card with $16 for labs.

How to survive

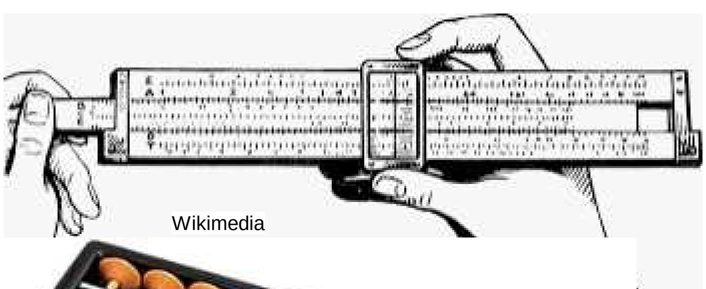
1. Easiest way to get through school is to actually learn and retain what you are asked to learn.
   Even if you're too busy, don't lose your good study practices. What you "just get by" on today will cost you later.

   Don't fall for the "I'll never need to know this" trap. Sure, much of what you learn you may not use, but you will need some of it, some day, either in the current class, future classes, or maybe sometime in your career. Don't waste time second-guessing the curriculum, It'll still be easier to just do your best to learn and retain what is covered.
2. Don't fall for the "traps".
   Homework answers, Problem session solutions, Posted solutions, Lecture notes.
3. KEEP UP! Use calendar.
4. Make "permanent notes" after you've finished a subject or section and feel that you know it.

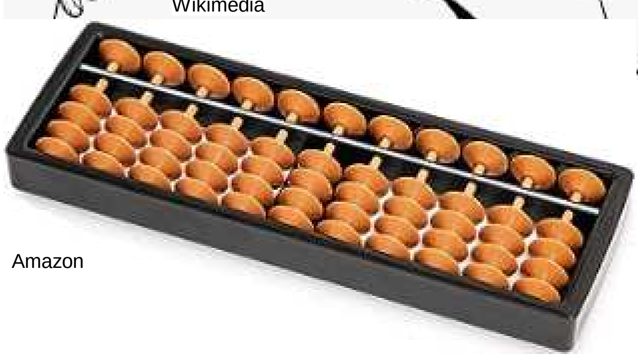
WHY? Why do you need some knowledge of electrical circuits?

1. Information processing. If you want to make anything interesting, your system or device will deal with information. Information like location, velocity, temperature, ph, flow rate, etc., etc. must be processed and acted on. Information can be read, processed, recorded and used to create results electrically much faster, cheaper and more accurately than any mechanical way. Some examples:

Mechanical



Wikimedia



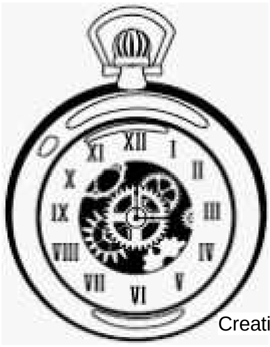
Amazon

VS

Electrical

TI

Mechanical | Electrical


Creativefabrica

< 3 bytes

VS


Amazon

$2^{32} = 4294967296$ bytes plus 1.2 GHz processor

= about 9 orders-of-magnitude more "memory"

Kodak

2 - 3 GB

Data Density

VS

Amazon

= about 2 orders-of-magnitude more

= about 100 raw images, or 35,000 jpegs

Or, just get one of these:


NBC

And there's a little matter of **speed**. Electrical systems perform 3 to 5 orders-of-magnitude faster.

2. Power and energy manipulation. In the 1800's steam engines dramatically changed people's lives. Later, internal combustion engines had a similarly dramatic effect, especially in transportation. For all other power needs, electricity took over, and it may soon displace internal combustion engines in vehicles. The upshot of this is that if you want to work in any field that supplies or uses energy, you'd better learn something about electricity.


Punch Newspapers

Thermal power plants can achieve above 60% efficiency. Wind and water turbines can do even better.


The Conversation

Power distribution systems can be 95% efficient


Tesla

Electric vehicles can be almost 90% efficient and typically harvest mechanical energy when decelerating.

$60\cdot\%\cdot 95\cdot\%\cdot 90\cdot\% = 51\cdot\%$

3. The study of basic circuits helps prepare you for the study of far more complex subjects later.
   Fluid Dynamics
   Heat Transfer
   Robotics

Internal combustion engines max out at about 25% and they never put gas back in your tank when you hit the brakes.

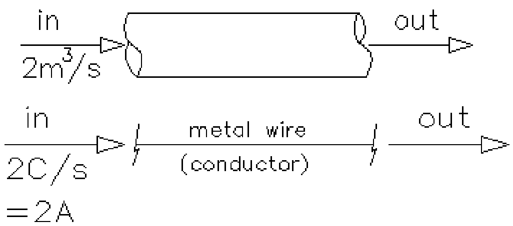

Autotrader

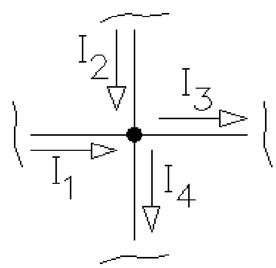
Lecture So, Let's get started...

Basic electrical quantities	**Letter used**	**Units**	**Fluid Analogy**
Charge, actually moves	Q	Coulomb (C)	m^3
Current, like fluid flow	$I = \frac{Q}{sec}$	Amp (A, mA, µA,...)	$\frac{m^3}{sec}$
Voltage, like pressure	V or E	volt (V, mV, kV,...)	$Pa = 1 \cdot \frac{N}{m^2}$

KCL, **K**irchhoff's **C**urrent **L**aw

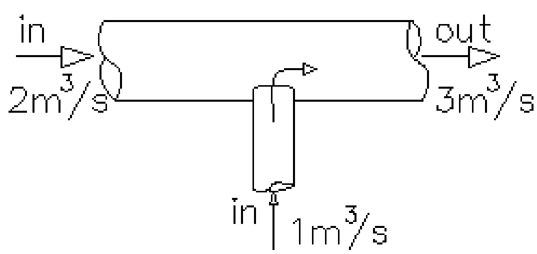
$I_{in} = I_{out}$ of any point, part, or section

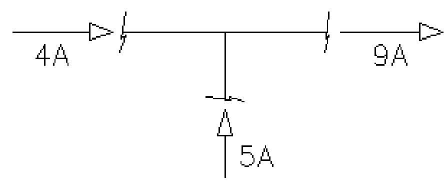


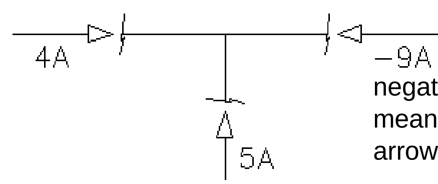


$I_{in} = I_{out}$

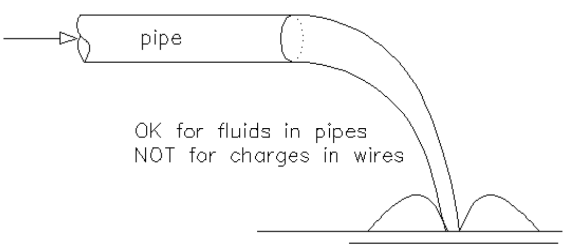
$I_1 + I_2 = I_3 + I_4$







negative current means the direction arrow is wrong



Electrical Conductors VS Nonconductors

Typically materials we would recognize as metals — Typically "nonmetals"

Required Simplifications (Almost true)

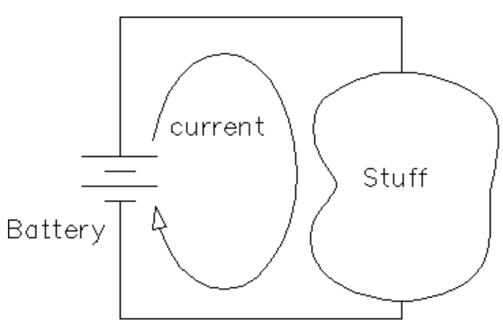
Electrical: Charges do not collect or "bunch up" anywhere. (No "static" electricity effects)

Fluids: Retain the same volume regardless of pressure. (Incompressible)

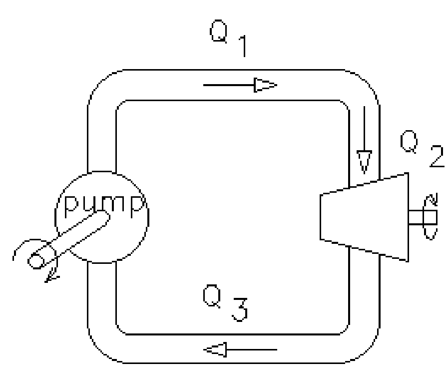
Battery also obeys KCL

No accumulation of charge anywhere, so it must circulate around.

Leads to the concept of a "Circuit"

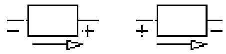


A circuit

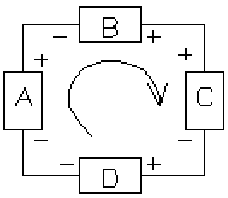


Voltage is like pressure
KVL, **K**irchhoff's **V**oltage **L**aw

$V_{gains} = V_{drops}$



around any loop



Massless fluid in our analogy
No gravity effects   No Bernoulli effects

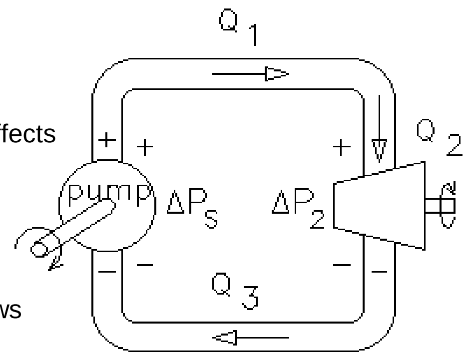
Reasonable because:

Electron mass is $9.11 \cdot 10^{-31} \cdot kg$

Election charge is $-1.6 \cdot 10^{-16} \cdot C$

Negative charge flows in negative direction

Fluid Analogy



Required Simplifications (Almost true)

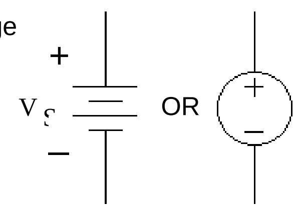
Electrical: All voltages differences are due to sources and current flows. Voltages require no time to "move" throughout the circuit.

Other voltage differences will equalize at nearly the speed of light-- fast enough for us to neglect.

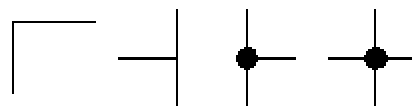
Fluids: All pressure differences are due to pumps and current flows. Pressures require no time to "move" throughout the system. Other pressure differences would equalize at the speed of sound in the fluid, which would be ∞ in an incompressible fluid.

Ideal elements in electrical circuit schematics

Batteries or voltage sources always the same voltage regardless of current.

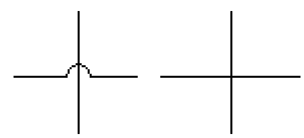


Ideal wire, assume no resistance to current flow



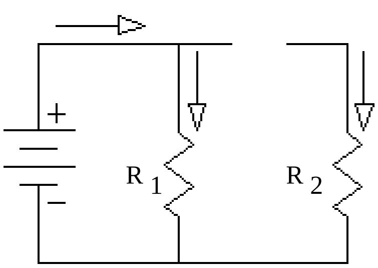
Connected wires

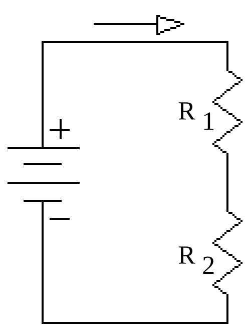
Ideal resistor, assume linear resistance to current flow

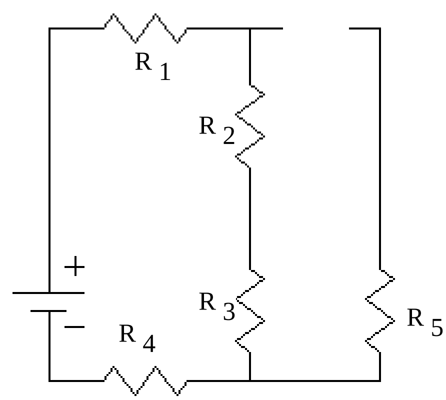


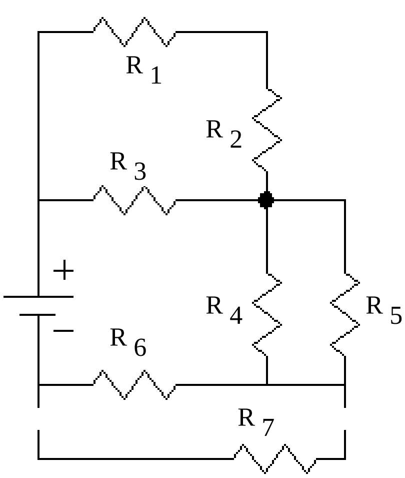
NOT connected

Take notes in class







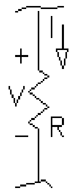


ECE 2210 Resistors, Ohm's Law, Dividers, Etc.

A. Stolp
1/28/06,
9/5/08,
8/21/23

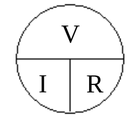
Ohm's law (resistors)

$$V = I \cdot R$$



$$I = \frac{V}{R}$$

$$R = \frac{V}{I}$$ definition of resistance and the unit "Ω"



The resistor color code as used on small resistors may be attached to this set of notes. For additional practical information see textbook section 3.5.

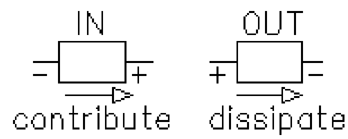
Power

flow $\frac{m^3}{sec}$ pressure $\frac{N}{m^3}$ flow x pressure: $\frac{m^3}{sec} \cdot \frac{N}{m^2} = \frac{m}{sec} \cdot \frac{N}{1} = \frac{N \cdot m}{sec} = \frac{Joule}{sec} = W$ = power

same for electricity power $P = I \cdot V$

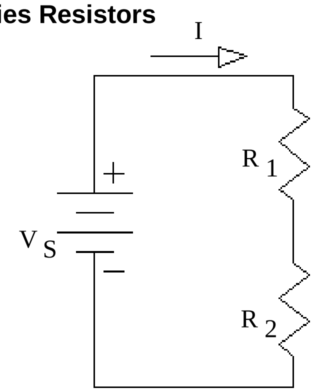
Power dissipated by resistors: $P = V \cdot I = \frac{V^2}{R} = I^2 \cdot R$

$P_{IN} = P_{OUT}$



Basic electrical quantities		Unit
Resistance	$R = \frac{V}{I}$	Ohm (Ω, kΩ, MΩ,...)
Conductance	$G = \frac{1}{R}$	Siemens (S, also mho, old unit)
Power energy/time	$P = V \cdot I$	Watt (W, mW, kW, MW,...)

Series Resistors

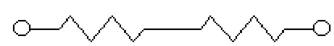


$V_1 = I \cdot R_1$

$V_T = V_1 + V_2$

$V_2 = I \cdot R_2$

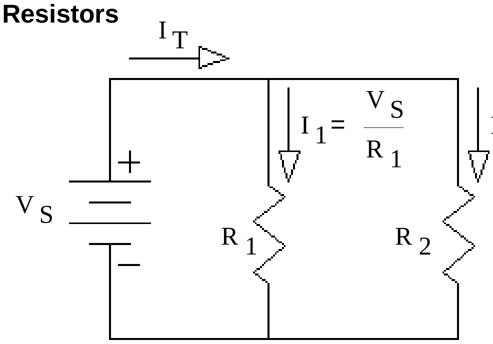
$$R_{eq} = \frac{V_T}{I} = \frac{V_1 + V_2}{I} = \frac{V_1}{I} + \frac{V_2}{I} = R_1 + R_2$$



$R_{eq} = R_1 + R_2$

Resistors are in series if and only if exactly the **same current** flows through each resistor.

Parallel Resistors



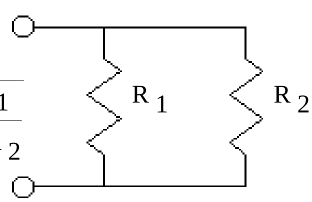
$I_1 = \frac{V_S}{R_1}$ $I_2 = \frac{V_S}{R_2}$

$$I_T = \frac{V_S}{R_1} + \frac{V_S}{R_2}$$

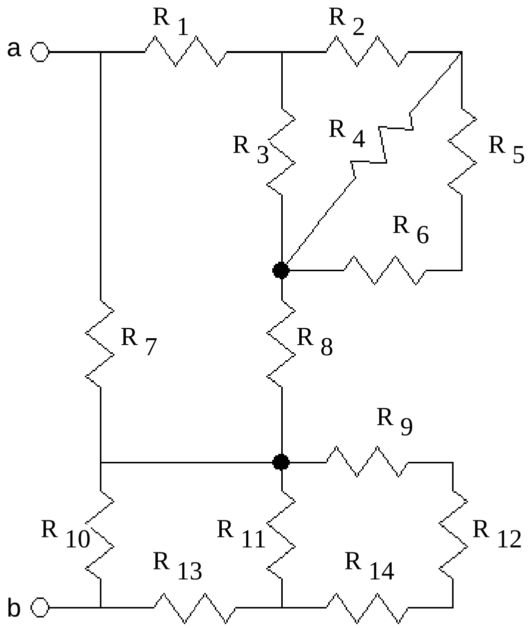
$$R_{eq} = \frac{V_S}{I_T} = \frac{V_S}{\frac{V_S}{R_1} + \frac{V_S}{R_1}} = \frac{1}{\frac{1}{R_1} + \frac{1}{R_2}}$$

Resistors are in parallel if and only if the **same voltage** is across each resistor.

$$R_{eq} = \frac{1}{\frac{1}{R_1} + \frac{1}{R_2}}$$



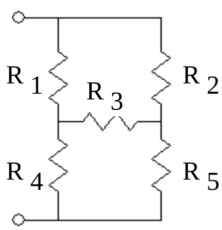
Series and Parallel (Look back at circuits on last page of Intro notes)



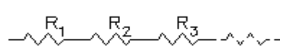
a O

b O

All resistor-only networks can be reduced to a single equivalent, but not always by means of series and parallel concepts.



Voltage Divider



series: $R_{eq} = R_1 + R_2 + R_3 + \ldots$

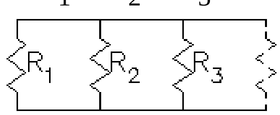
Exactly the **same current** through each resistor

Voltage divider:

$$V_{Rn} = V_{total} \cdot \frac{R_n}{R_1 + R_2 + R_3 + \ldots}$$

Current Divider

parallel: $R_{eq} = \dfrac{1}{\dfrac{1}{R_1} + \dfrac{1}{R_2} + \dfrac{1}{R_3} + \ldots}$

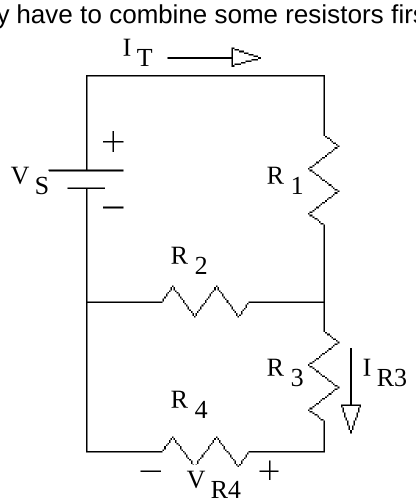


Exactly the **same voltage** across each resistor

current divider:

$$I_{Rn} = I_{total} \cdot \frac{\dfrac{1}{R_n}}{\dfrac{1}{R_1} + \dfrac{1}{R_2} + \dfrac{1}{R_3} + \ldots}$$

May have to combine some resistors first to get series and parallel resistors to use with divider expressions.

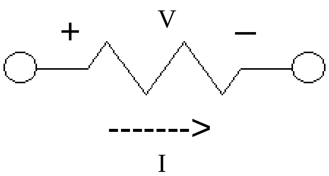


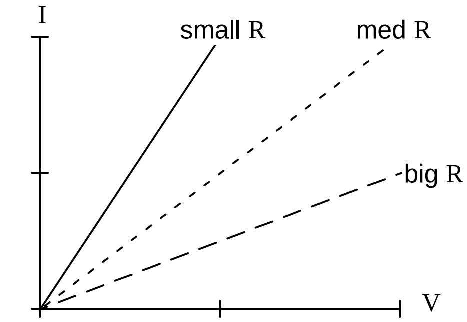
$V_{R4} =$

$I_T =$

$I_{R3} =$

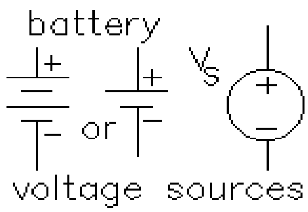
Resistors



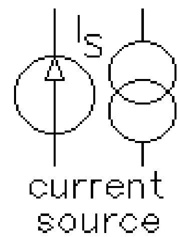


$$R = \frac{1}{\text{slope}} = \frac{\Delta V}{\Delta I}$$

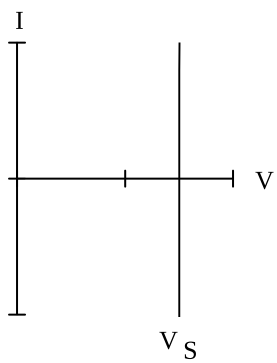
Sources

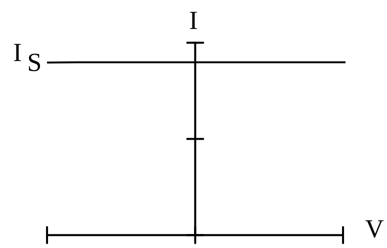


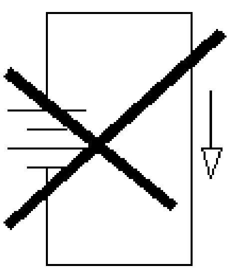
Battery Cell



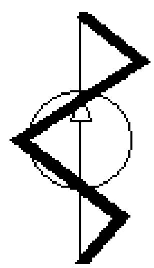
Less intuitive, less like sources we are used to seeing.



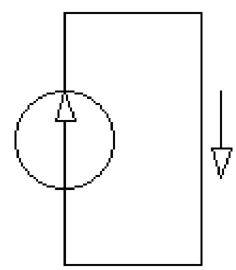




Doesn't make sense with for ideal voltage sources and ideal wires

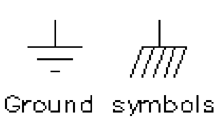


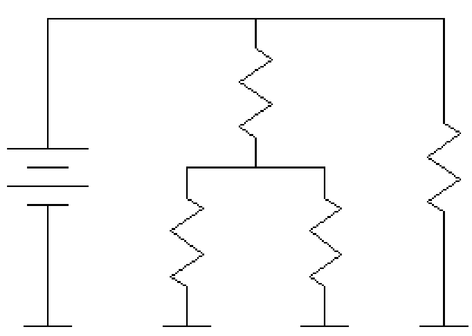
Doesn't make sense for ideal current sources

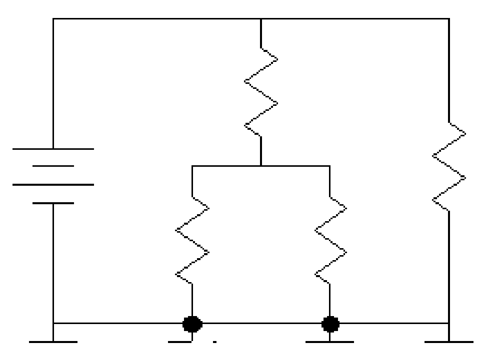


Must have a path for the current to flow

Ground



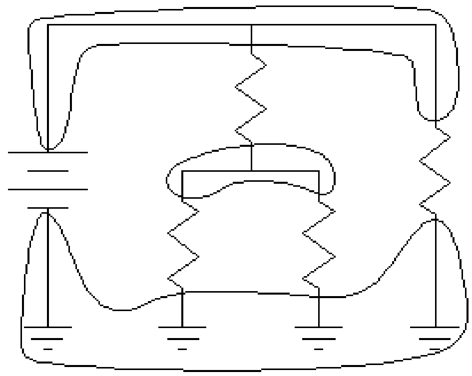




Ground is considered zero volts and is a reference for other voltages.

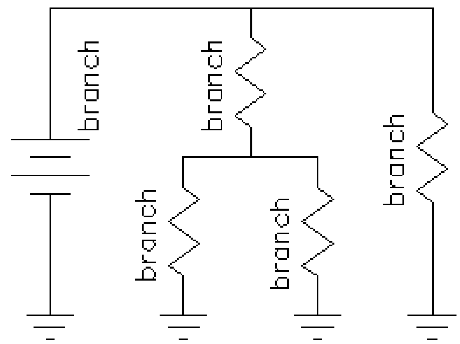
Nodes & Branches

Node = all points connected by wire, all at same voltage (potential)

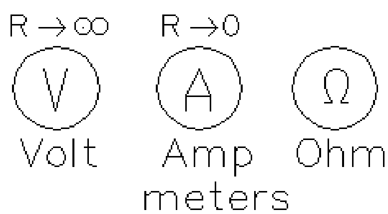


ground is a node

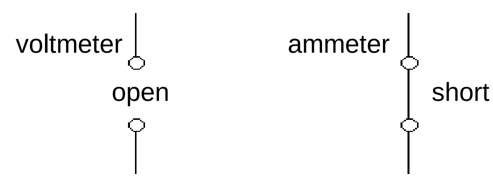
Branch = all parts with the same current



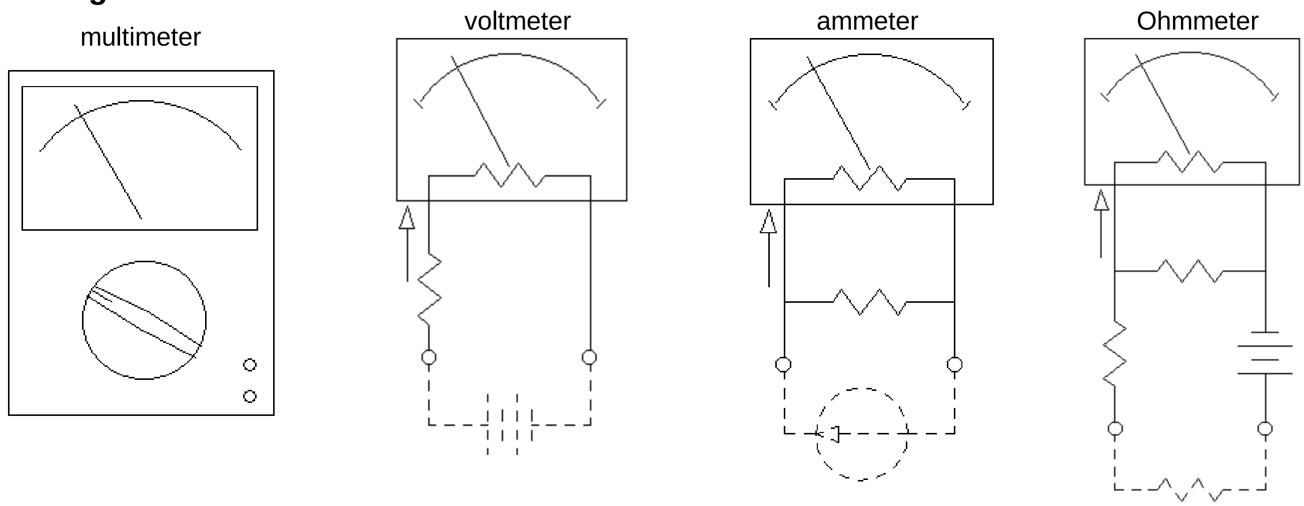
Meters



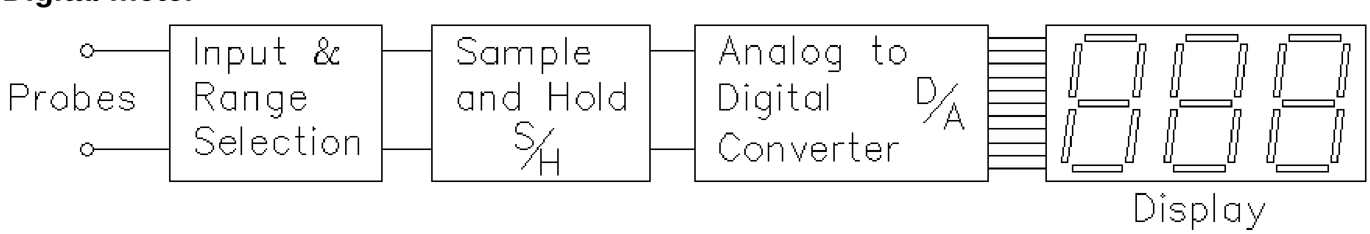
ideally:



Analog meters

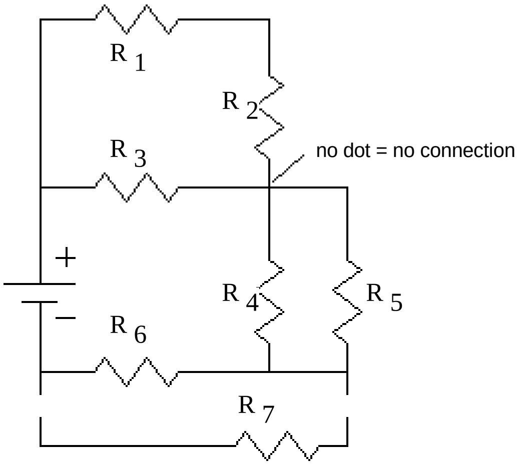


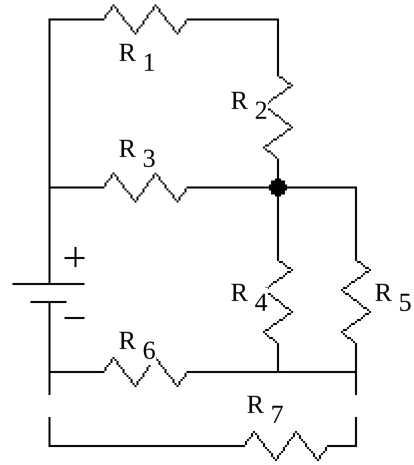
Digital meter

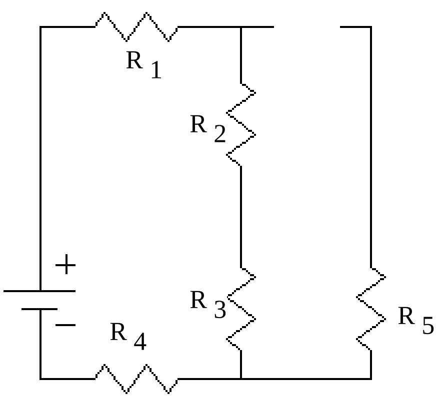


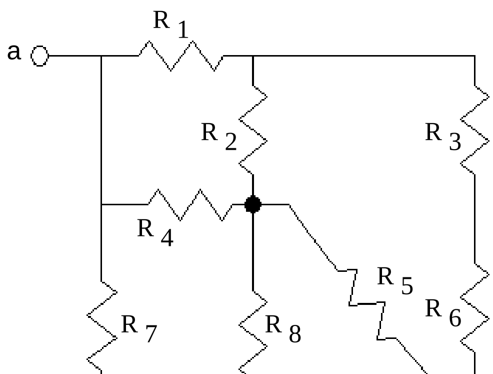
Additional Examples (time permitting)

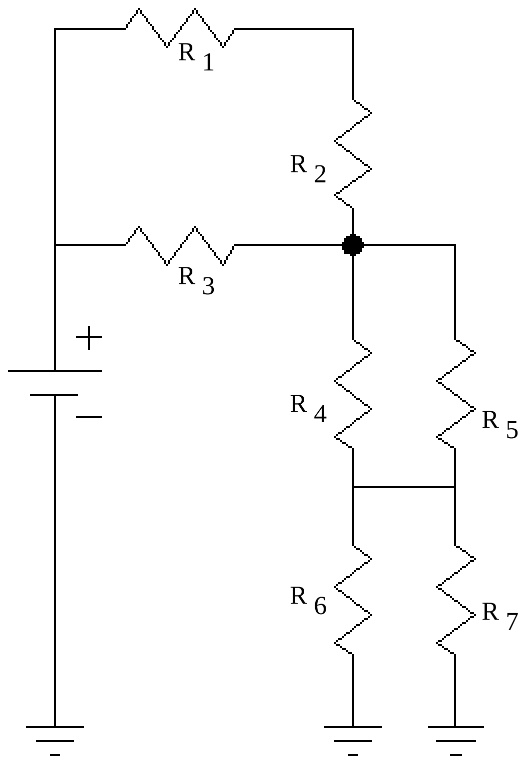
Take notes in class

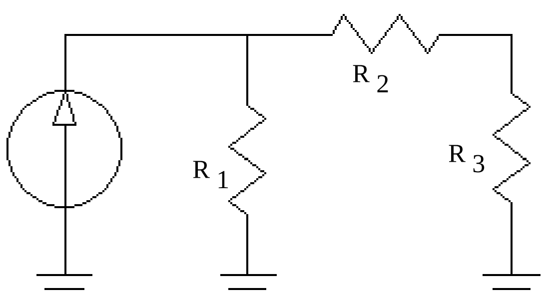


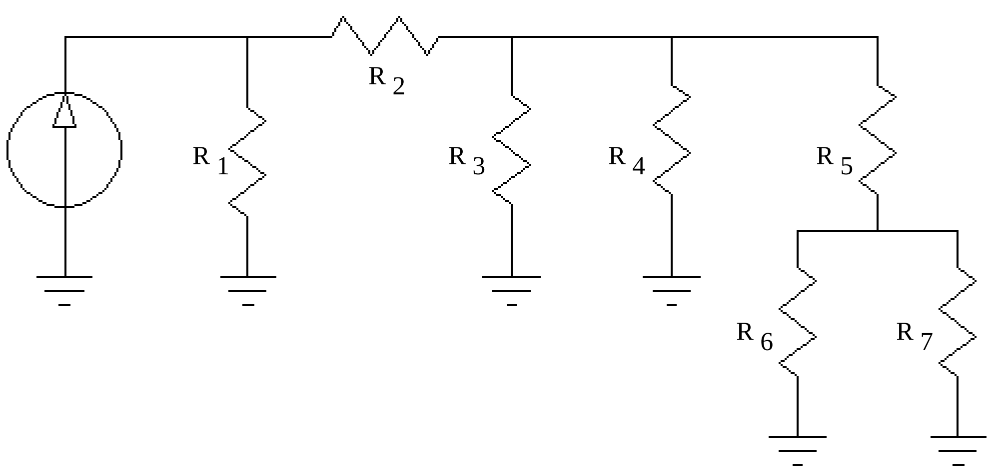












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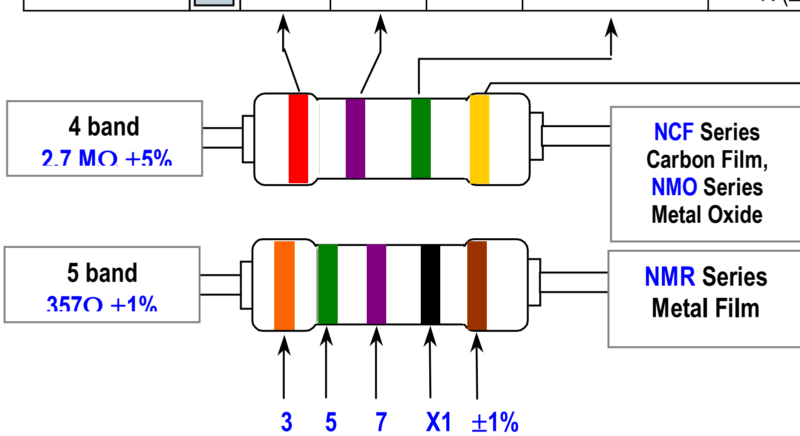
PRODUCT GUIDE FROM NIC Components

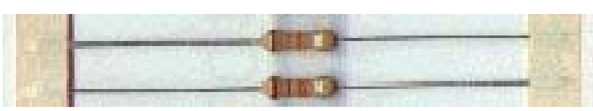
RESISTOR COLOR CODING CHART

PRODUCTS: AXIAL LEADED RESISTORS
SERIES: NCF, NMR & NMO

Resistor Color Coding Chart

Color		*Significant Figure* 1st	2nd	3rd	*Multiplier*	*Tolerance*
Black		0	0	0	1	-
Brown		1	1	1	10	F (±1%)
Red		2	2	2	100	G (±2%)
Orange		3	3	3	1,000	-
Yellow		4	4	4	10,000	-
Green		5	5	5	100,000	D (±0.5%)
Blue		6	6	6	1,000,000	C (±0.25%)
Violet		7	7	7	10,000,000	B (±0.1%)
Grey		8	8	8	-	-
White		9	9	9	-	-
Gold		-	-	-	0.1	J (±5%)
Silver		-	-	-	0.01	K (±10%)





Standard ±5% (J) Values

E24
1.1
1.2
1.3
1.5
1.6
1.8
2.0
2.2
2.4
2.7
3.0
3.3
3.6
3.9
4.3
4.7
5.1
6.2
6.8
7.5
8.2
9.1

Standard ±1% (F) Values

E96	E96	E96	E96
1.00	1.78	3.16	5.62
1.02	1.82	3.24	5.76
1.05	1.87	3.32	5.90
1.07	1.91	3.40	6.04
1.10	1.96	3.48	6.19
1.13	2.00	3.57	6.34
1.15	2.05	3.65	6.49
1.18	2.10	3.74	6.65
1.21	2.15	3.83	6.81
1.24	2.21	3.92	6.98
1.27	2.26	4.02	7.15
1.30	2.32	4.12	7.32
1.33	2.37	4.22	7.50
1.37	2.43	4.32	7.68
1.40	2.49	4.42	7.87
1.43	2.55	4.53	8.06
1.47	2.61	4.64	8.25
1.50	2.67	4.75	8.45
1.54	2.74	4.87	8.66
1.58	2.80	4.99	8.87
1.62	2.87	5.11	9.09
1.65	2.94	5.23	9.31
1.69	3.01	5.36	9.53
1.74	3.09	5.49	9.76

Ohm = **Ω**
1000 = **K**
1Million = **M**
1ohm = 0.001 K
10 ohm = 0.01 K
100 ohm = 0.1K
1000 ohm = 1.0K
10,000 ohm = 10K
100,000 ohm = 100K =0.1M
1,000,000 ohm = 1000K = 1M

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