ELECTRICITY 101

a very basic review

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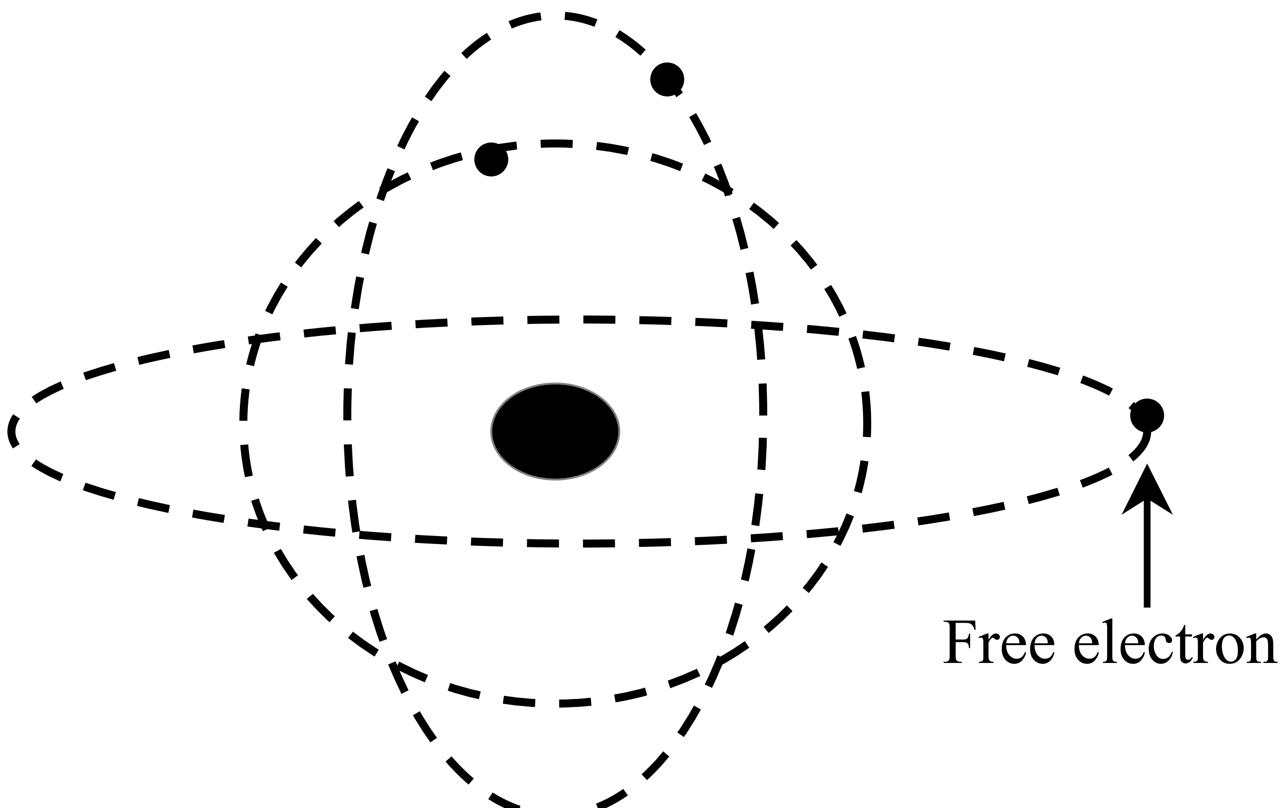
The basis for electricity – the atom with its electron "cloud".



CONDUCTORS / SEMI-CONDUCTORS

ELEMENT	AL	FE	CU	AG	AU	C	SI	GE
ATOMIC #	13	26	29	47	79	6	14	32
ATOMIC WT	27	56	63	108	197	12	28	72
CONDUCTIVITY	2.6	9.7	1.7	1.6	2.4	1400	85000	45
VALENCE	+3	+2	+1	+1	+1	±4	±4	±4

Earth resistivities

Physical composition	Resistivity Ohm-cm	Resistivity Ohm -meter
Sea Water	100 - 200	1 - 2
Marsh	200 - 300	2 - 3
Clay	300 - 16k	3 - 160
Clay, sand, gravel	1k - 135k	10 - 1.4k
Chalk	6k - 40k	60 - 400
Shale	10k - 50k	100 - 500
Sand	9k - 80k	90 - 800
Sand, gravel	30k - 500k	300 - 5k
Rock	50k - 1m	500 - 10k

Range: Conductors to insulators

- Conductors: metals with crystalline structure and “free” electron cloud.
- Ionized gasses.
- Semiconductors - ‘tailor-made’ conductivity.
- Insulators: barely perceptible conductivity.
- A vacuum is the perfect insulator, yet a stream of electron particles and electro-magnetic waves can travel through it.

Electricity:
an energy transfer medium

- FLOW: Source → conduction medium → load → conduction medium → back to source.
  - A COMPLETE CIRCUIT
  - OBEYS THE 'CONSERVATION OF ENERGY' LAW
- Flow of electrons vs. flow of normal current
  - Ben Franklin GOT IT WRONG!
  - ELECTRONS FLOW FROM A – SOURCE TO A + SINK, NORMAL CURRENT FLOW IS VICE VERSA

Two ‘types’ of electricity

- Direct Current (DC)
  - Steady on or off characteristic
  - A battery
  - Static discharge
  - Lightning
- Alternating Current (AC)
  - Changes repeatably with time at some characteristic frequency
  - Household power
  - Audio: speech, music
  - AM/FM radio, TV
  - Cell phone, satellite
  - Radar, microwaves

Define “current”

- ~ 6 x 10^{18} (billion, billion) electrons per second past a single point = 1 Ampere of current.
- The symbol is ‘ I ’
- It flows – like water in a pipe
- 1 milliAmp (mA) = 1/1,000 Ampere
- 1 microAmp (uA) = 1/1,000 mA = 1/1,000,000 Ampere

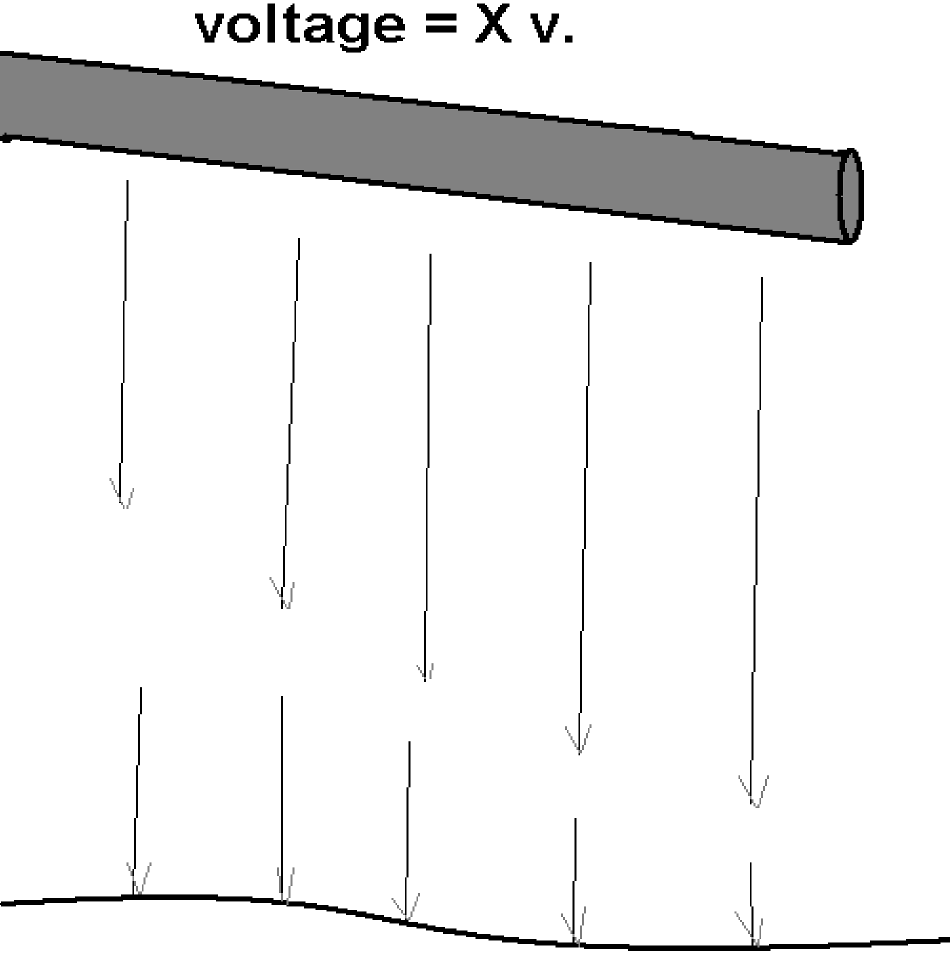
Define “voltage”

- Very hard to define using basic units
  (1 Newton force exerted over 1 meter distance in 1 second = 1 Watt
  1 Watt / 1 Ampere = 1 Volt)
- Easier to have a ‘feel’ for voltage levels 1.5 v. battery, 9 v. battery, 12 v. battery, 120 v rms house system, etc.
- Voltage is a pressure pushing electrons to form a current. It is like “head” in a water system or the height of a waterfall.
- The symbol is ‘ V ‘

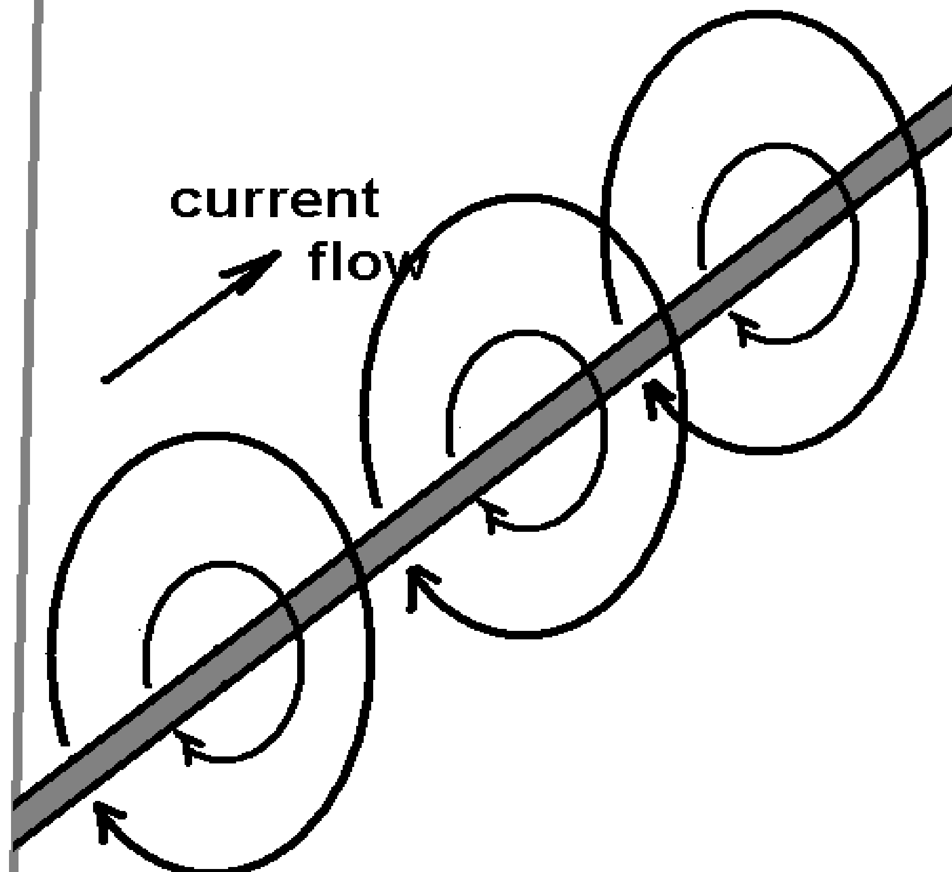
Define "resistance"

- 1 Volt/1 Amp = 1 Ohm
- Is like the diameter of a water pipe – small diameter (greater resistance) means less flow is possible, larger diameter (less resistance) means greater flow is possible.
- For a given diameter pipe (fixed resistance), increasing the pressure (voltage) will increase the water flow (current).
- Symbol is R
- Range of practical resistance values is very large
  - micro-ohms, milli-ohms, ohms, kilo-ohms, mega-ohms, giga-ohms.
- Can be lumped or distributed

Fields



An Electric field
measured in volts/meter



A Magnetic field
measured in milligauss

What is a circuit?

- **Current will <u>only</u> flow if one has a complete “circuit” path which allows current produced by a NON-ZERO voltage to return to its source.**
- **All paths have *some* level of resistance which defines the amount of current a given voltage can produce.**
- **Current follows all paths back to its source in inverse proportion to their resistance.**

Ohm's Law - not just a good idea, … … … … it's the law!

- $R = V / I$; $I = V / R$; $V = I \times R$
- POWER, $P = V * I$, or $= V^2 / R$, or $= I^2 * R$
- power (watts) not the same as energy (work measured in Joules).
  - POWER DELIVERED OVER TIME IS ENERGY.
- It is extremely important to realize the implications of voltage as either a source or as a potential difference (drop).

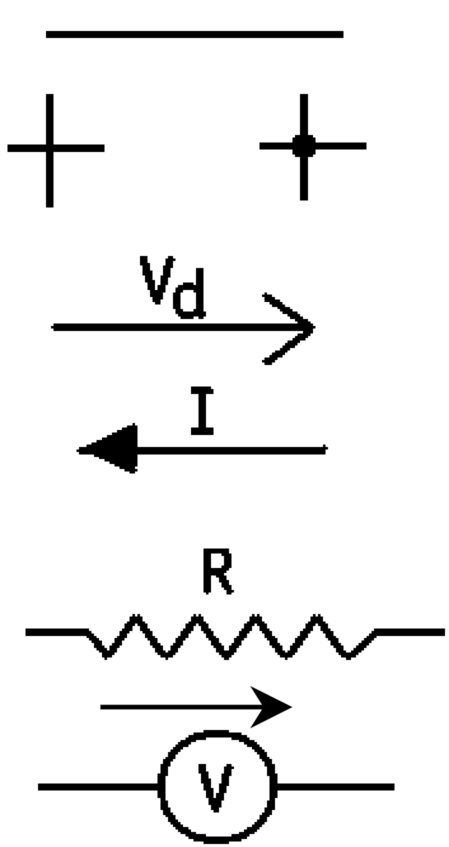
Examples:

- A voltage source of 5 volts AC rms is producing a current of 2 Amps AC rms into a resistance. What is the resistance?
- A 0.25 Ohm resistance has a current of 4 Amps AC rms running through it. What voltage drop is across this resistance?
- A voltage source of 3.6 Volts AC rms feeds a circuit with a total resistance of 1.2 Ohms, what is the current flowing?
- How much power is produced when a current of 16 Amps AC rms flows through a wire with a resistance of 0.012 Ohms?

Answers:

- **Given that V=5v. and I=2A. Then, R=V/I, so R=5/2=2.5 Ohms.**
- **Given that R=0.25 Ohm and I=4 A. Then V=I*R, so V=0.25*4=1v. AC rms**
- **Given that V=3.6v. and R=1.2 Ohms Then I=V/R, so I=3.6/1.2=3A. AC rms**
- **Given that I=16A. and R=0.012 Ohm Then $P=I^2*R$, so P=16*16*0.012=3.072 Watts**

Schematic symbols



CONDUCTOR

NO CONNECTION / CONNECTION

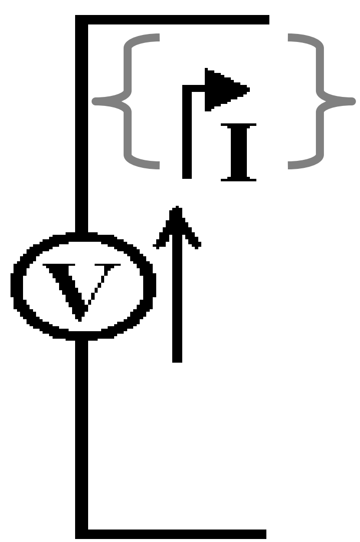
VOLTAGE DROP

CURRENT FLOW

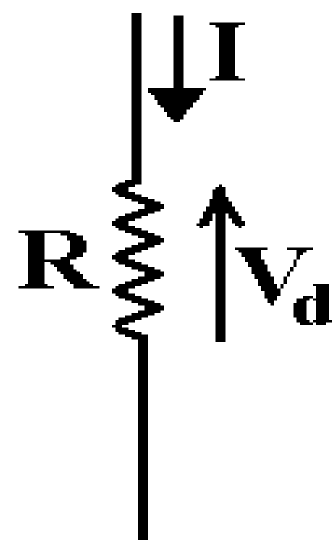
RESISTANCE

VOLTAGE SOURCE

Difference between voltage drop and voltage source.



Voltage source



Voltage drop

Combining resistances:

- Series: They add algebraically:
  - Rt = R1+R2+R3+….+Rn
- Parallel: They add inverses to form an inverse sum:
  - 1/Rt = 1/R1+1/R2+1/R3+….+1/Rn
  - Special case of two resistors in parallel, the combined resistance is the product divided by the sum of the two resistors.
    - Rt = [R1*R2]/[R1+R2]

Resistance simplification:

- Series string: 4, 1.5, 2.3, 5.1 Ohms What is the total resistance?
- Parallel combination of 3.6 and 2.4 Ohm: what is the equivalent resistance?
- Parallel resistances: 2.4, 4.8, 6, 0.8 Ohms, what is the equivalent resistance?
- What is the resistance of a 4 Ohm resistor in series with a parallel combination of a 2.4 Ohm and a 1.6 Ohm resistor?

Resistance answers:

- Sum the resistors: 4+1.5+2.3+5.1 = 12.9 Ohms.
- Product over sum: [3.6 * 2.4] over [3.6+2.4] = 8.64/6 = 1.44 Ohms
- The "hard way":

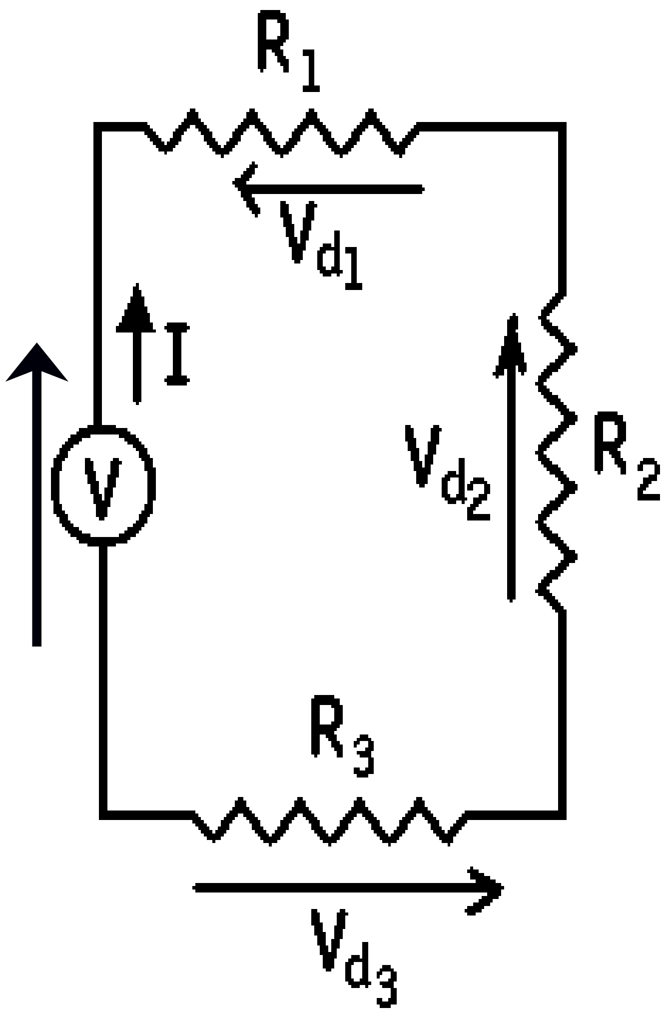
(1/2.4)+(1/4.8)+(1/6)+(1/0.8) = 0.417+0.208+0.167+1.25 = 2.042

lastly, Rt = 1/2.042 = 0.49 Ohms.

- First do the parallel pair: (2.4*1.6)/(2.4+1.6)=0.96 Ohms in series with 4 Ohms gives a total of 4.96 Ohms.

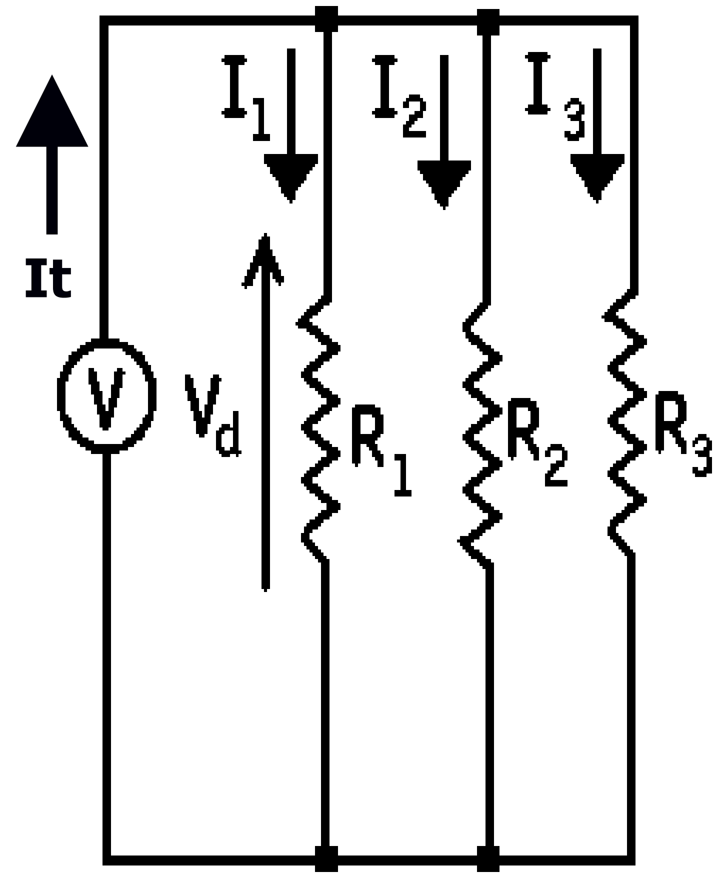
Basic circuit types

SERIES



Common current

PARALLEL

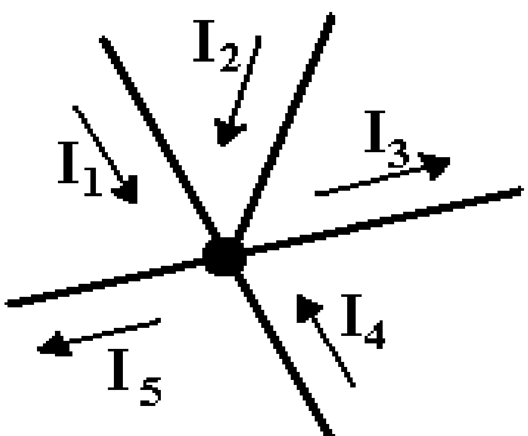


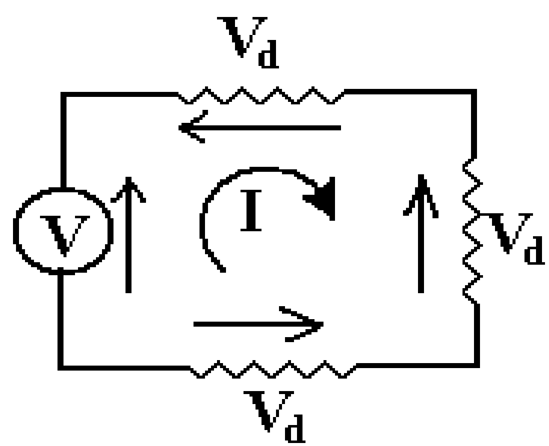
Common voltage

Kirchhoff's Laws

$$\sum I_{point} = 0$$

$$\sum V_{closed\ loop} = 0$$



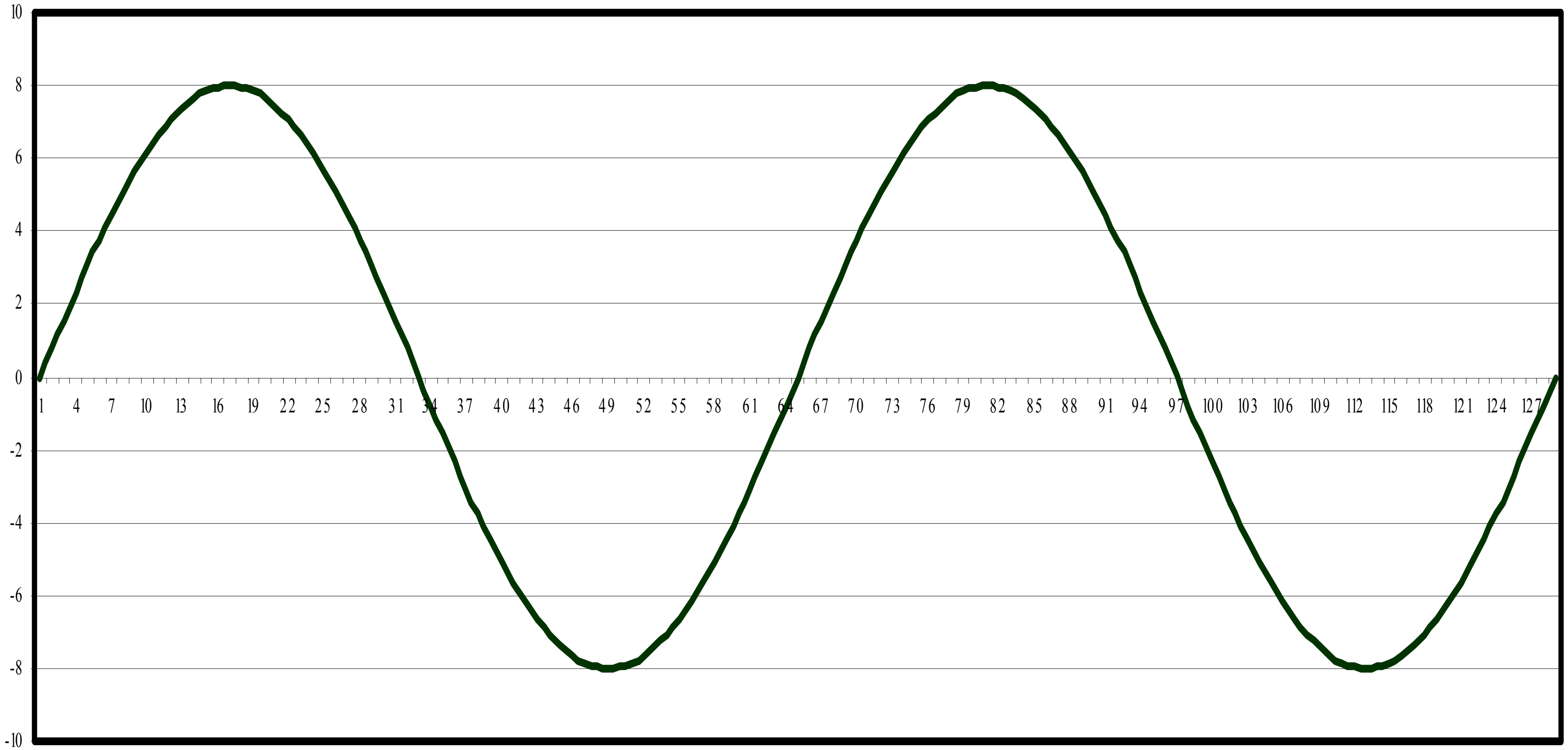


The sum of all currents is zero

The sum of all voltage drops = the sum of all voltage sources

60 Hz AC waveform

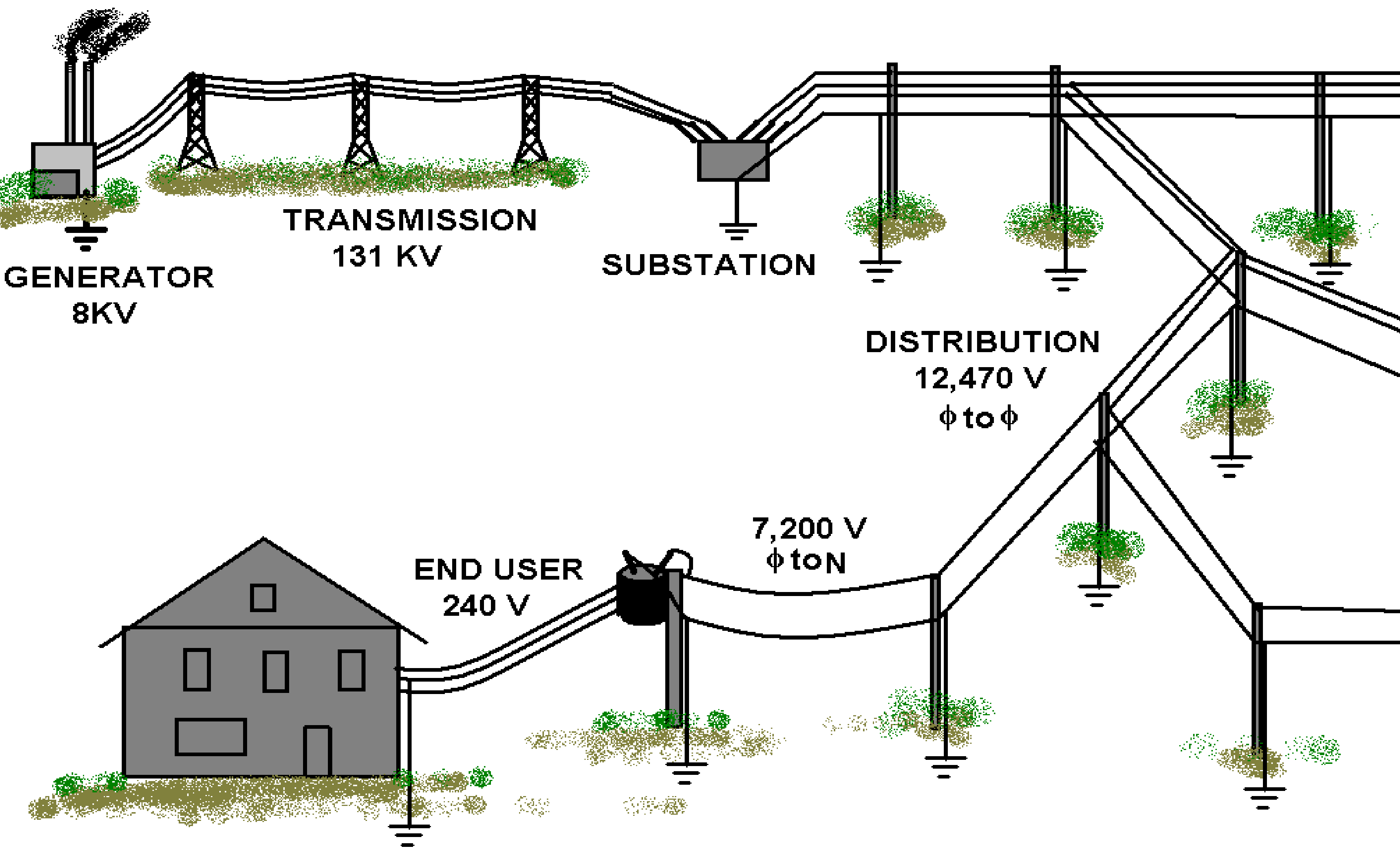
sinewave



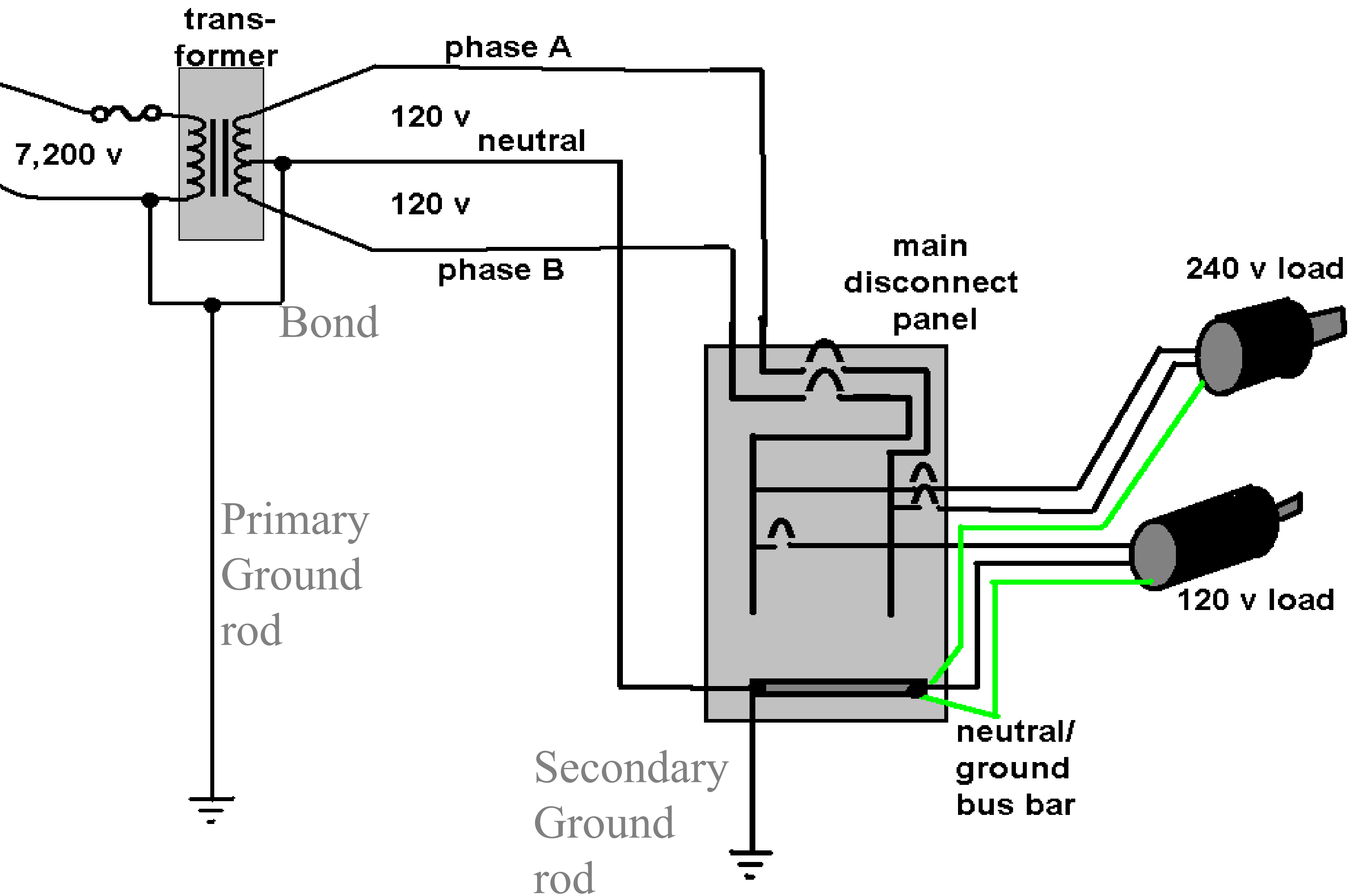
AC measurements

- Not polar : no permanent + and - to worry about
- can be expressed as a root mean square (rms) voltage or current
- RMS has the same “ heating value” as DC of the same level.
- 16 Volts peak to peak is 8 Volts peak is 5.656 Volts rms (multiply by .707)

The nation's AC electrical system



Farm electrical system



Questions??