Lecture 2

31 January, 2011

Announcements (1/31/11)

- 401B and 501B:
  - Laboratory Meeting Tues Feb 1, 4^{00}-7^{00} pm
- Electricity Test in 2 weeks (Feb 14)
- Today's lecture … 3^{00}-4^{00}, 5^{00}-6^{00}
- 3x5 Cards

Foundations:

Basic Electricity
Basic Neurophysiology
Basic Neuroanatomy

Part I: Basic Electricity

- Prelude
- Atomic Stuff
- Voltage, Resistance, Current, Power, Energy
- DC Series Circuits
- DC Parallel Circuits
- AC Circuits in brief

Prelude: Scale of Measurement

- Deci = 10^{-1}
- Centi = 10^{-2}
- Milli = 10^{-3}
- Micro = 10^{-6}
- Nano = 10^{-9}
- Pico = 10^{-12}
- Fento = 10^{-15}

- Kilo = 10^{3}
- Mega = 10^{6}
- Giga = 10^{9}
- Tera = 10^{12}

Bits, Bytes, Mega, Giga, Tera (explained)
1 bit = a 1 or 0 (b)
4 bits = 1 nybble (?)
8 bits = 1 byte (B)
1024 bytes = 1 Kilobyte (KB)
1024 Kilobytes = 1 Megabyte (MB)
1024 Megabytes = 1 Gigabyte (GB)
1024 Gigabytes = 1 Terabyte (TB)

What’s a Trillion $ (Tera $)

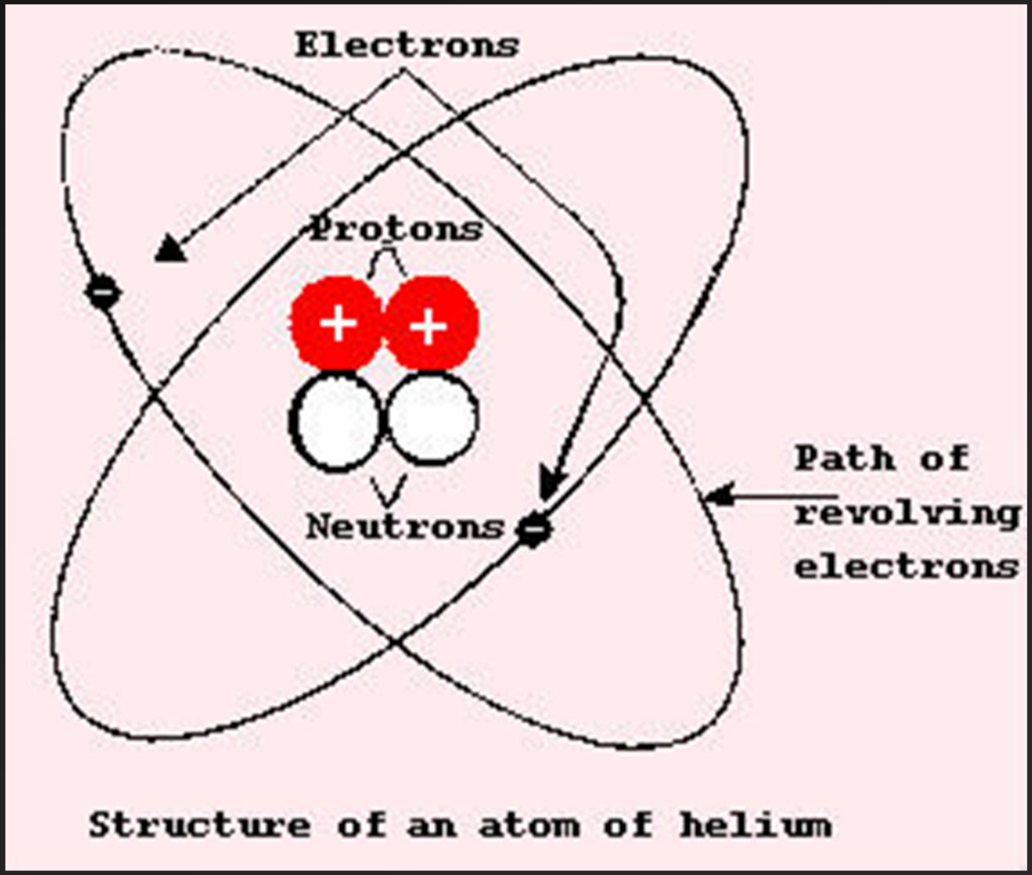
http://www.pagetutor.com/trillion/index.html

Prelude: 3 Great Forces

- Nuclear — Strong, very short (subatomic) distances …
- Electrostatic — Holds all kinds of stuff together in the everyday world
- Gravitational — Weakest, but impressive over very large distances and with large masses

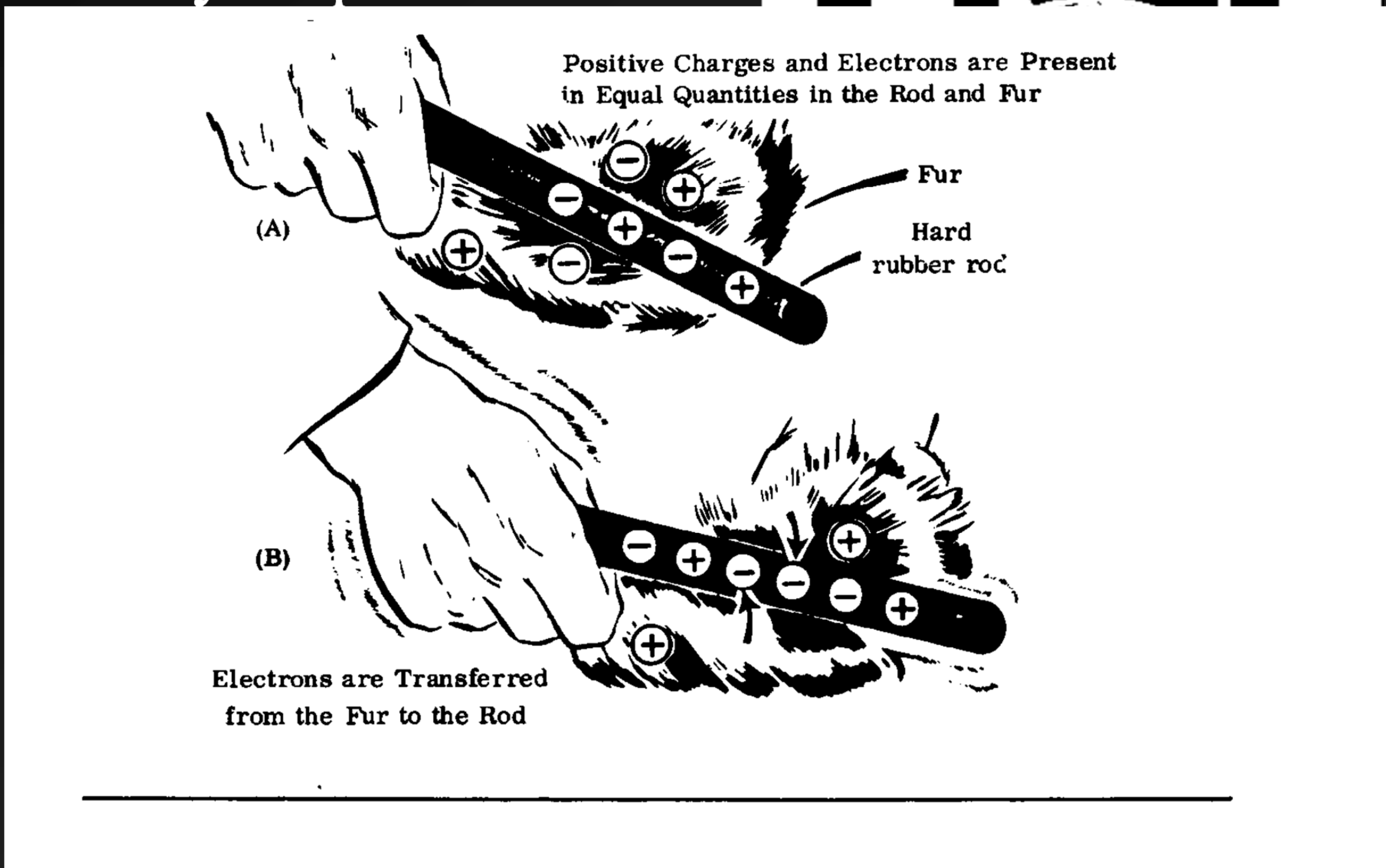
Electrostatic Forces

- Due to charged subatomic particles
  - Proton
  - Electron
  - but not Neutron
- The Law:
  - Unlike Charges Attract
  - Like Charges Repel



Free Electrons

- Some electrons can be easily displaced

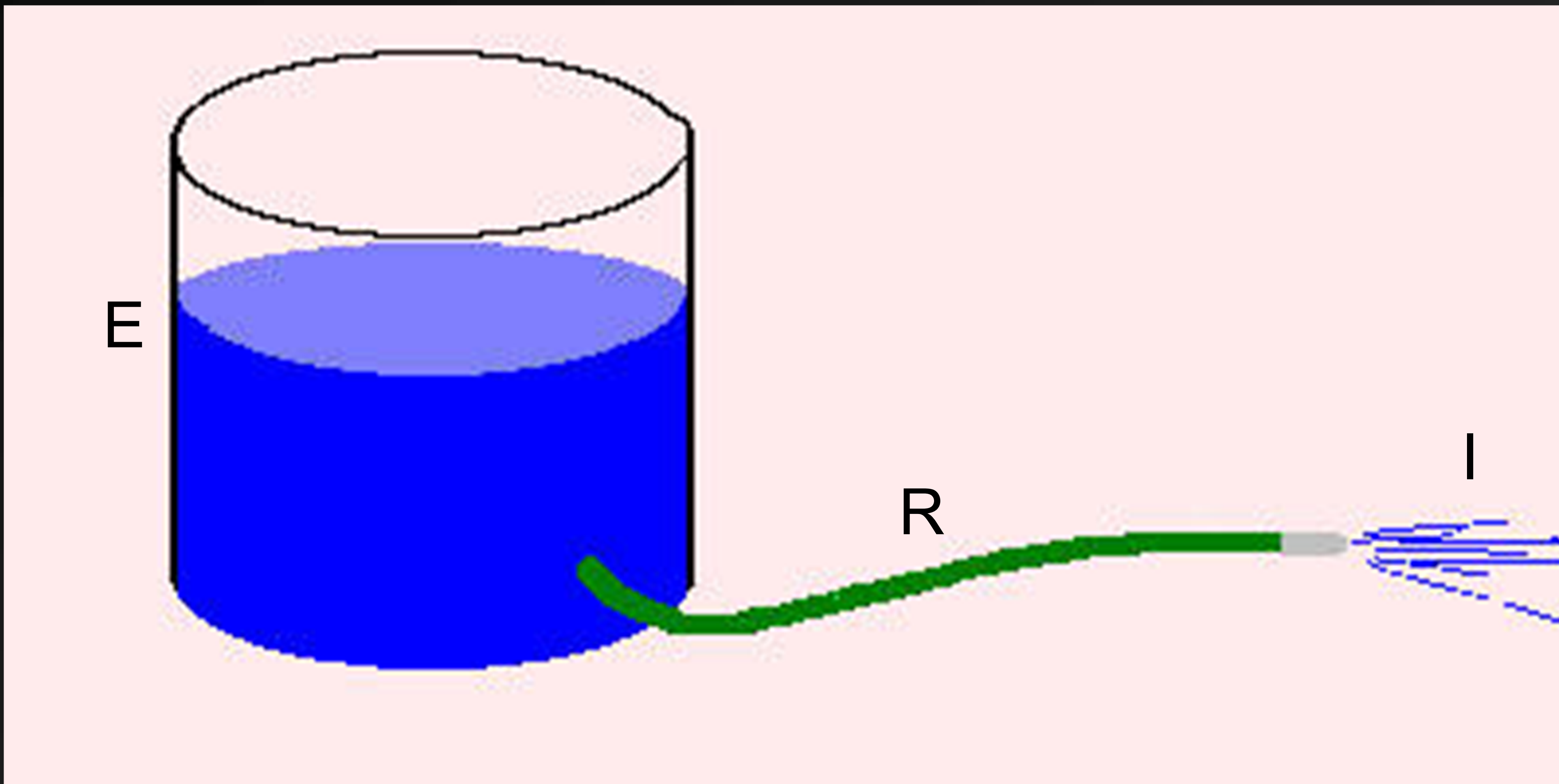


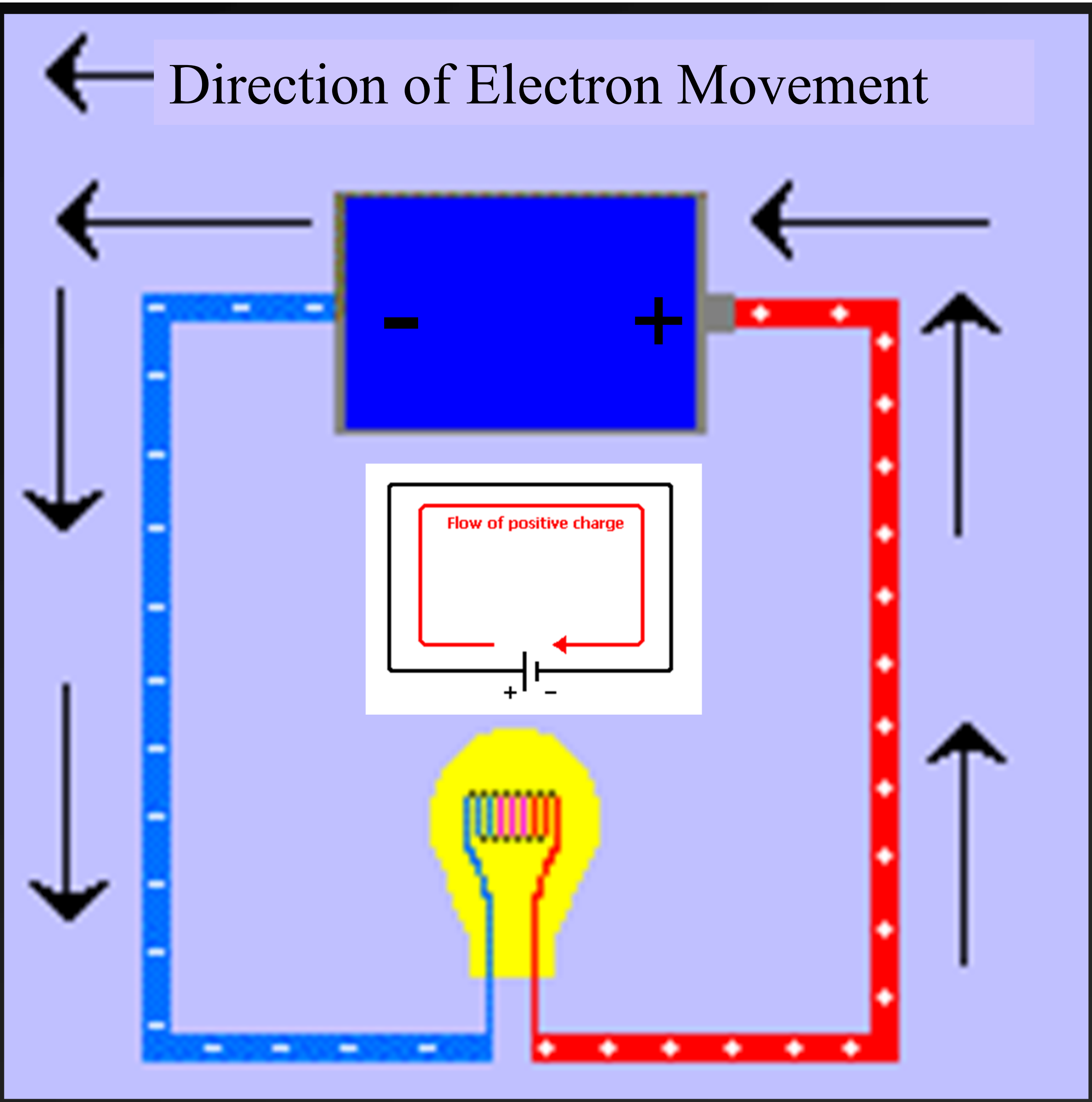
Demo

Static Electricity

- Friction with Poor Conductors
- Electrons displaced from one substance to the other (e.g Hair to comb, carpet to body)
- Leads to voltage potential (i.e., difference)

Basic Electricity by Analogy





DC
Anyway!

Details Details

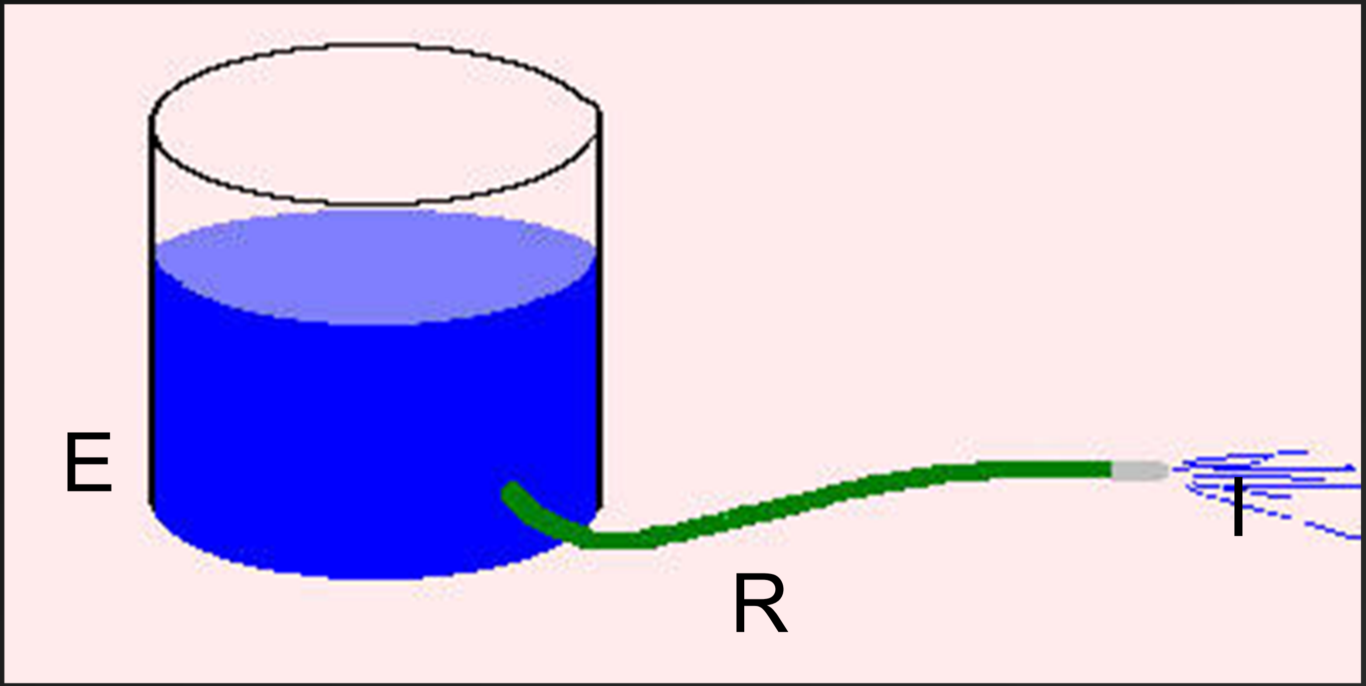
Symbol	Term	aka	Unit
E	Voltage	Electromotive Force	Volts (V)
I	Current	Rate of Flow	Amperes (A)
R	Resistance	--	Ohm (Ω)
P	Power	Rate of work	Watt (w)
W	Energy	Ability to do work	Watt-Second (Joule)

Ohm’s Law

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

$$E = IR$$

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



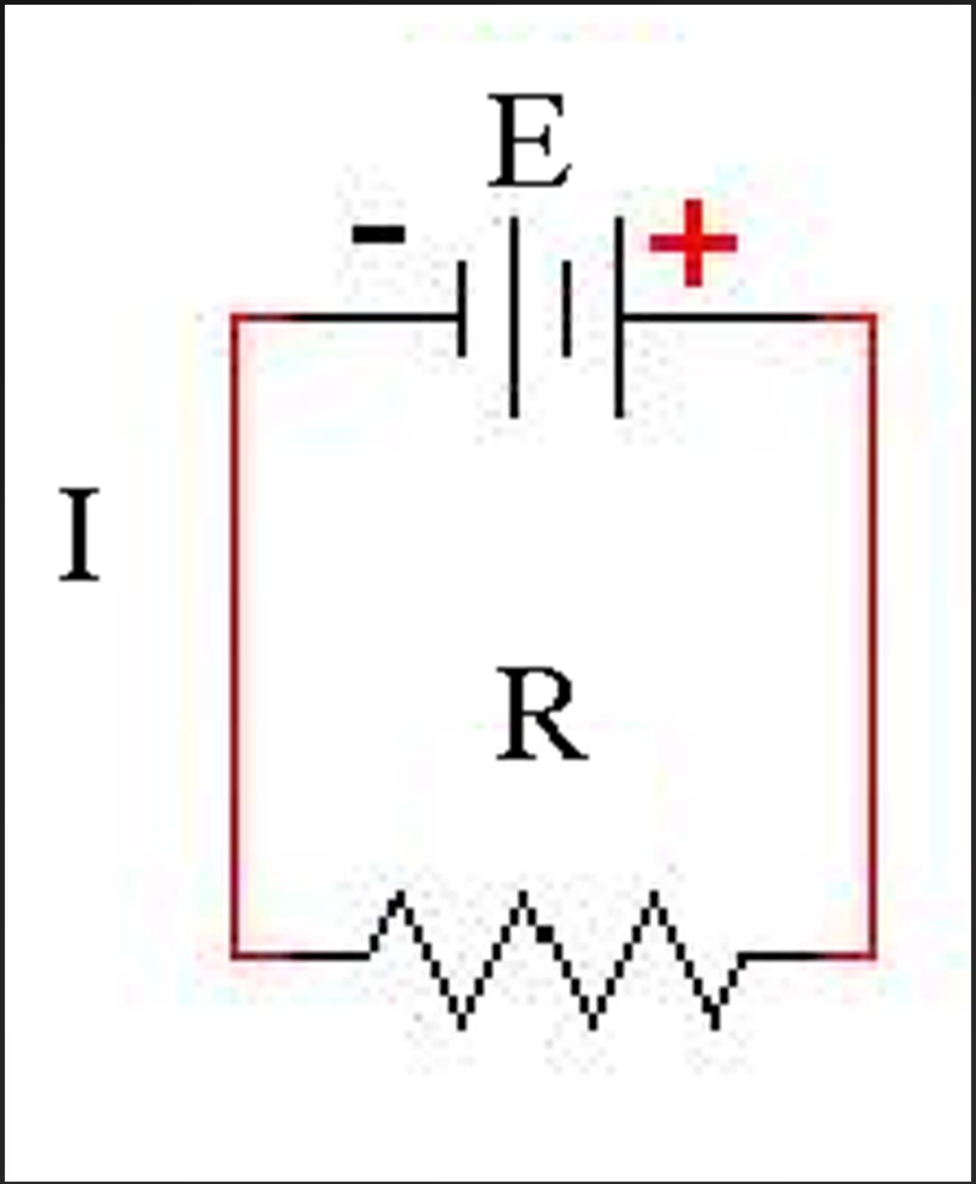
See also: http://www.falstad.com/circuit/e-ohms.html

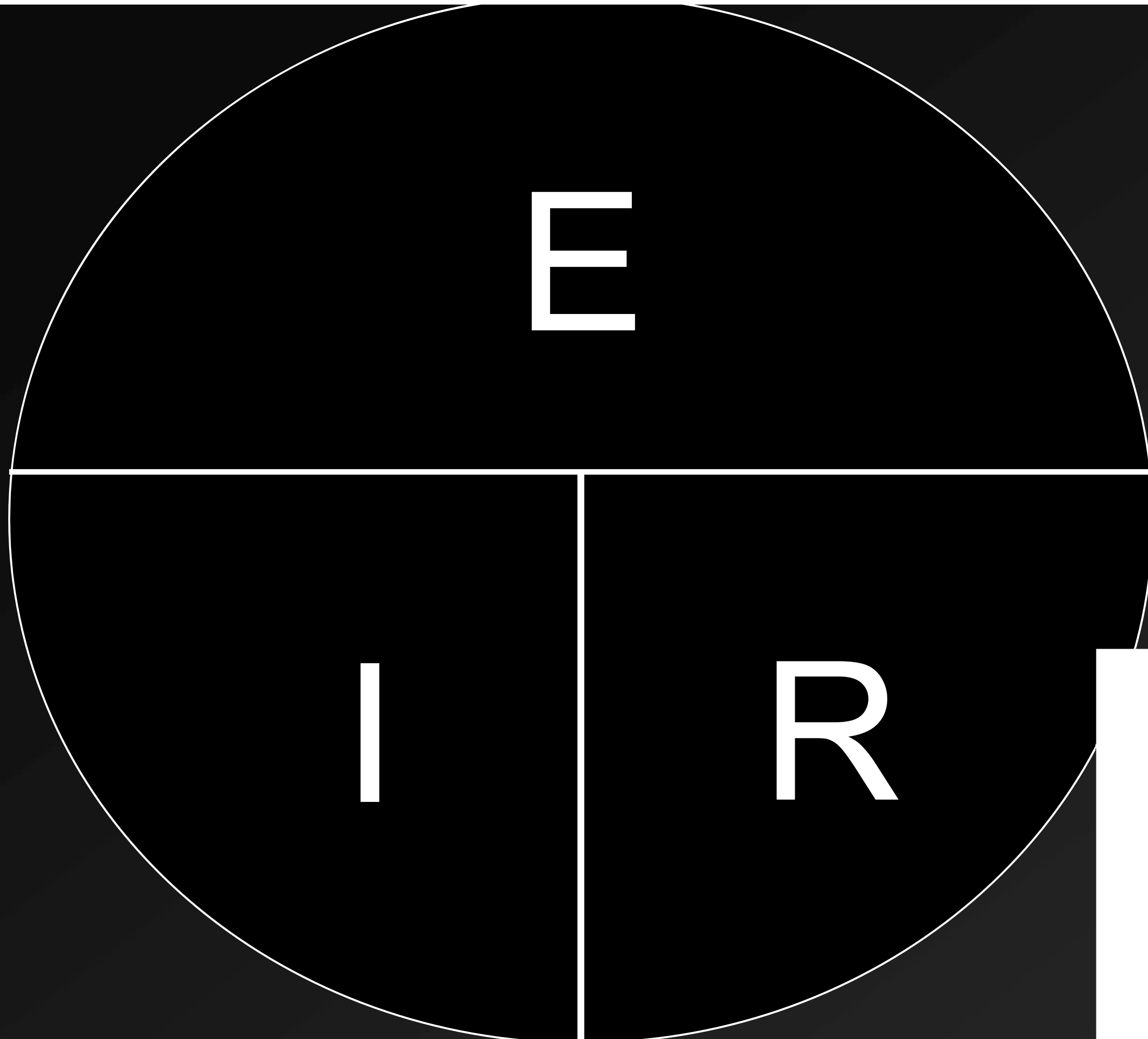
Ohm's Law

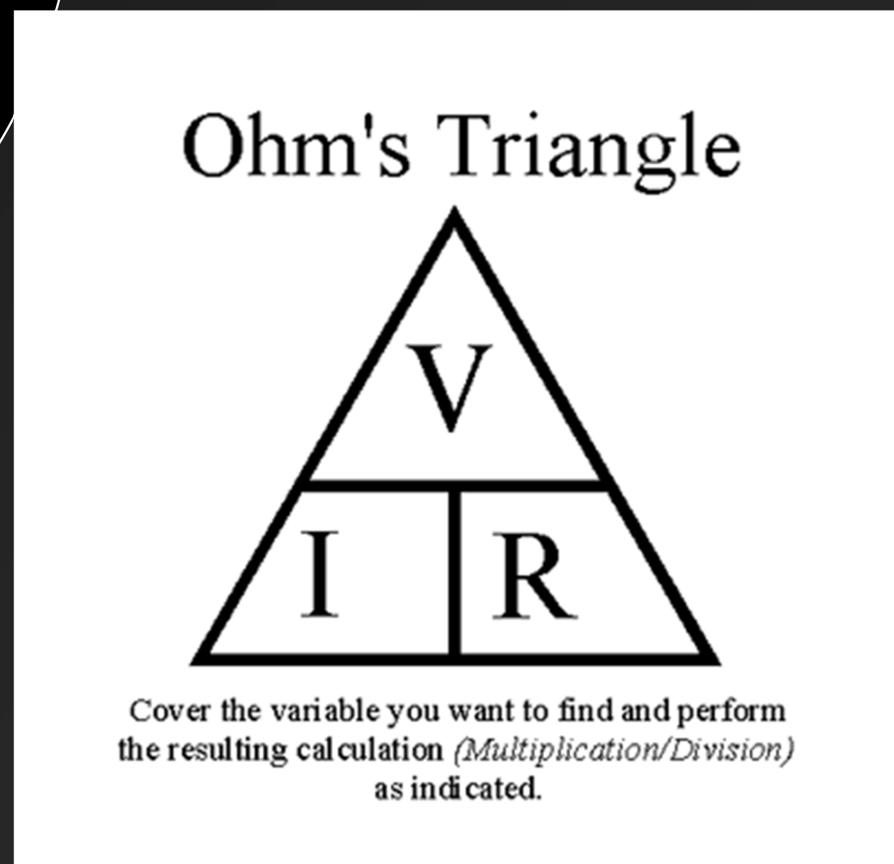
$$I = \frac{E}{R}$$

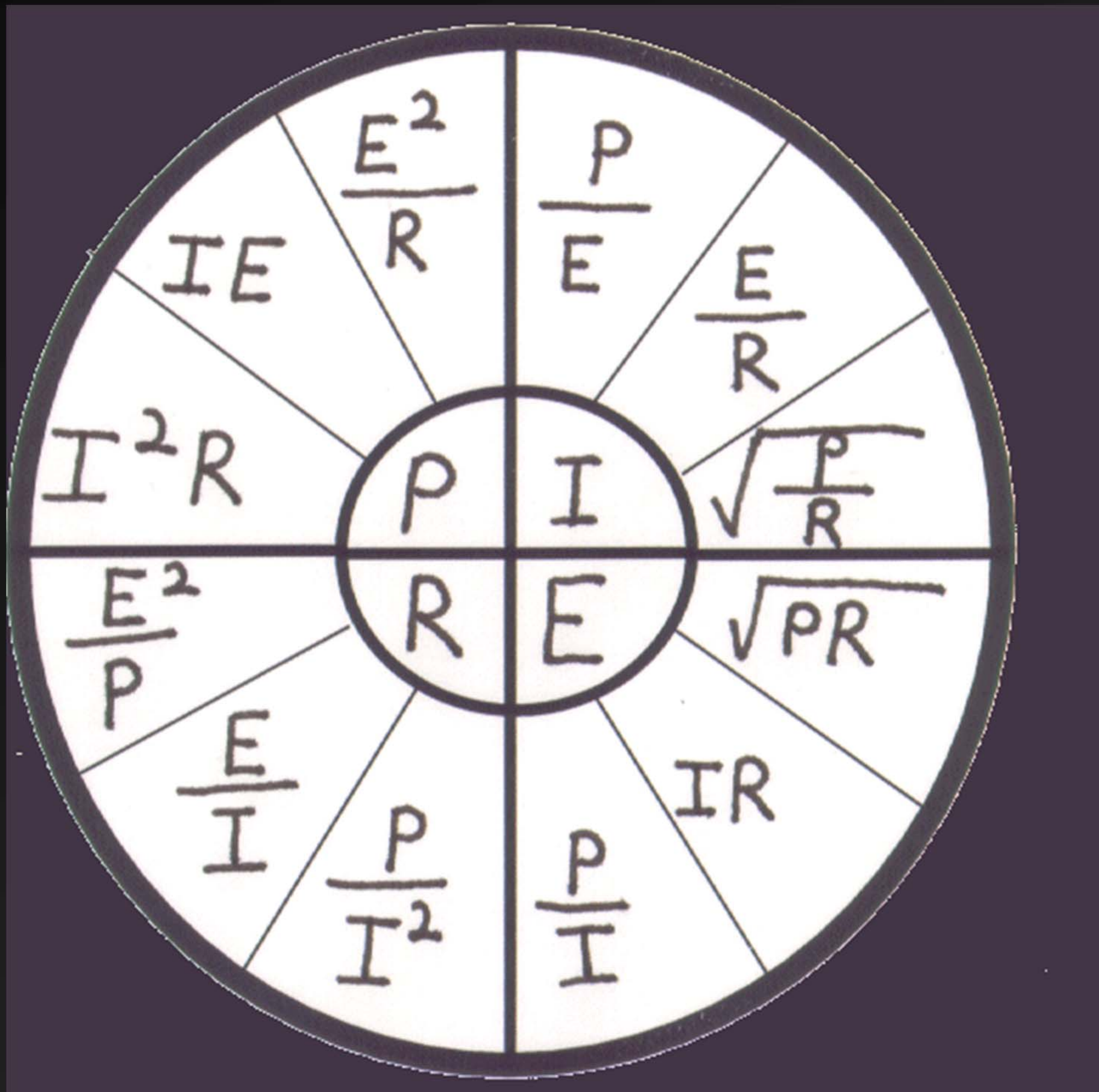
$$E = IR$$

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

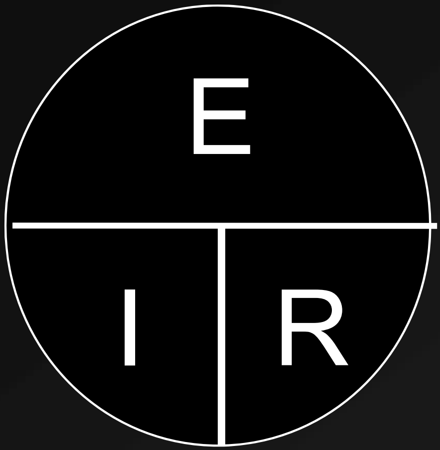


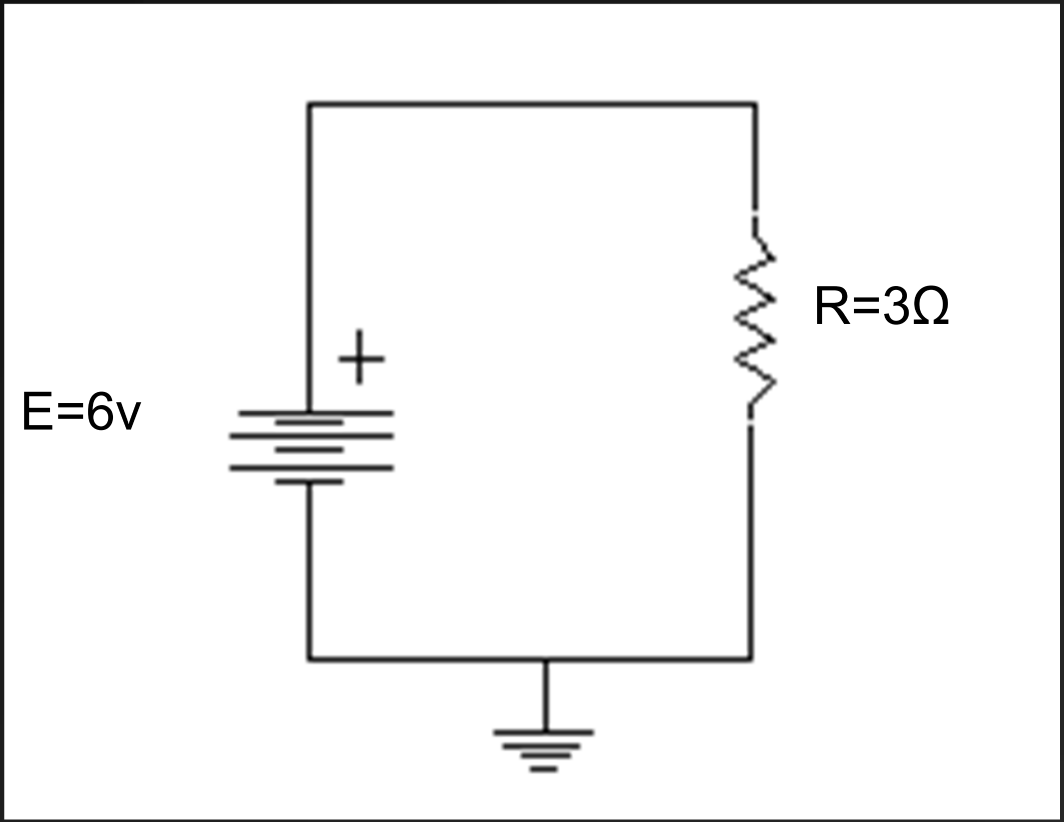

E
I
R


Ohm's Triangle
V
I
R
Cover the variable you want to find and perform the resulting calculation (Multiplication/Division) as indicated.


P
I
R
E
$\frac{E^2}{R}$
$\frac{P}{E}$
$\frac{E}{R}$
$\sqrt{\frac{P}{R}}$
$\sqrt{PR}$
IR
$\frac{P}{I}$
$\frac{P}{I^2}$
$\frac{E}{I}$
$\frac{E^2}{P}$
I^2R
IE

Basic Circuit

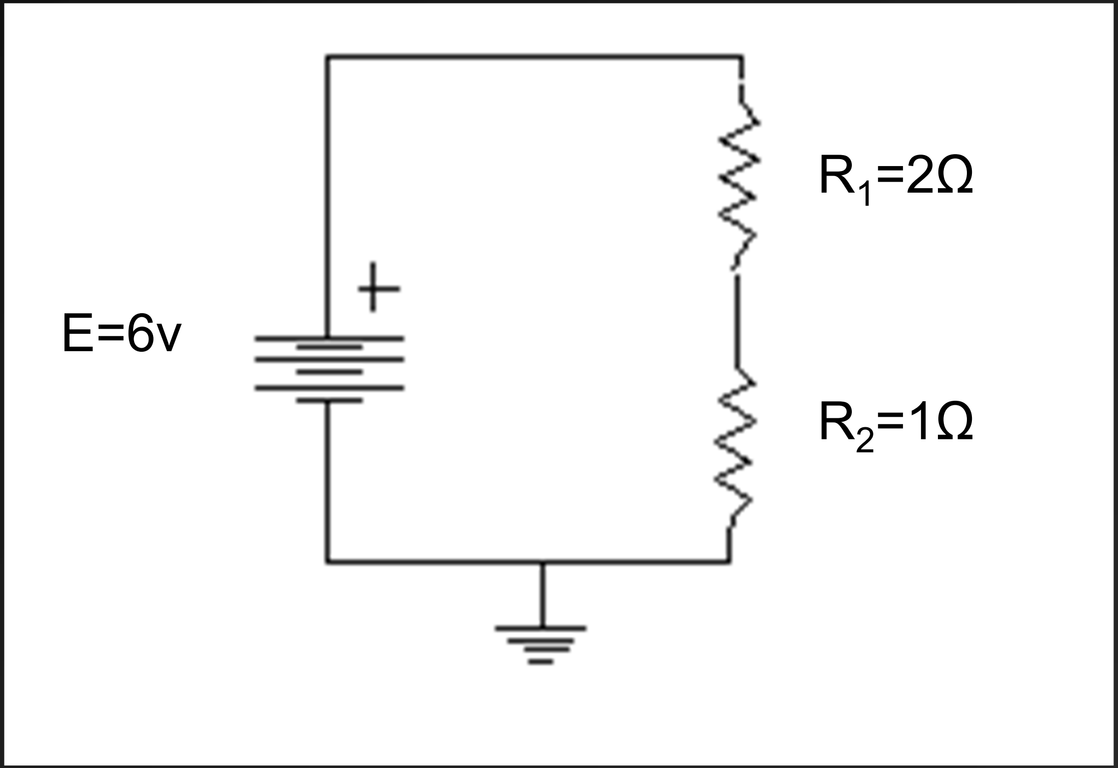




I = ?

Volt-Ohm Meter Demo

Series Circuit



$$R_T = R_1 + R_2$$

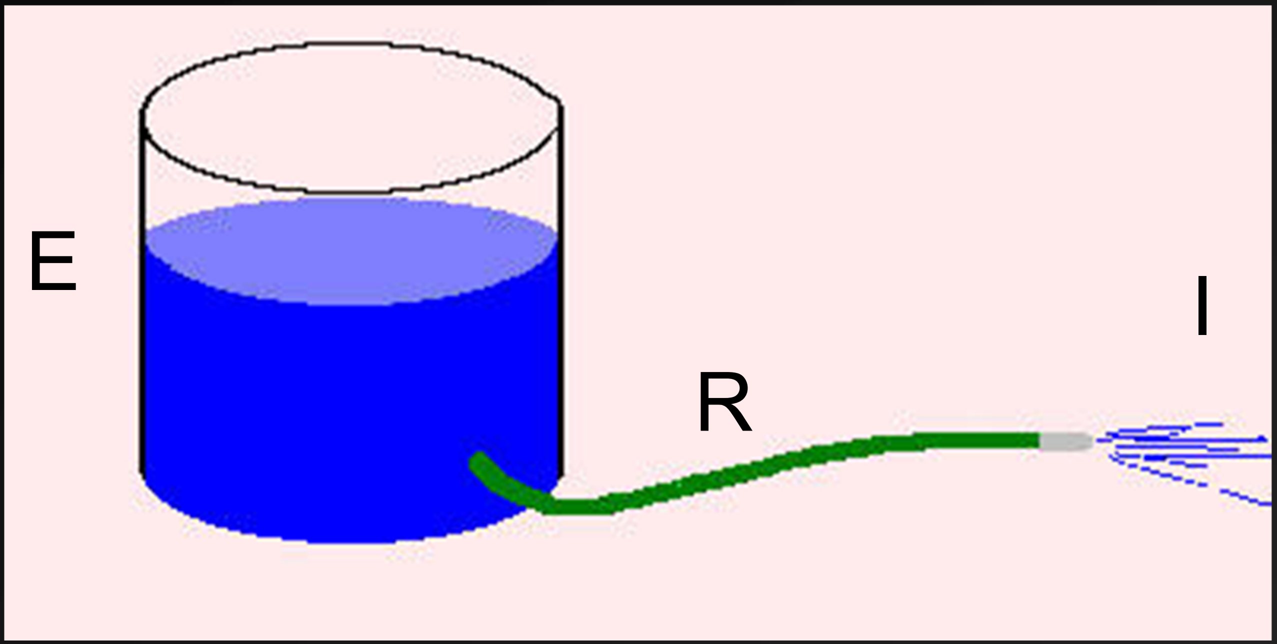
I = ?

E_{R1}=?

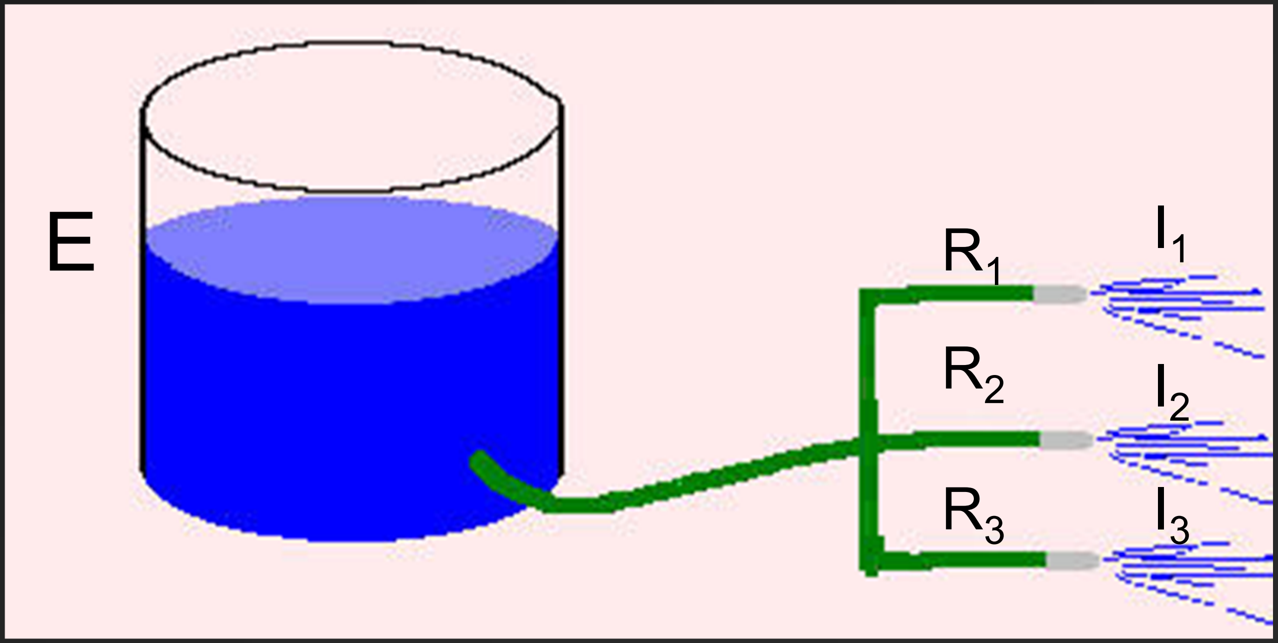
E_{R2}=?

Java Demo

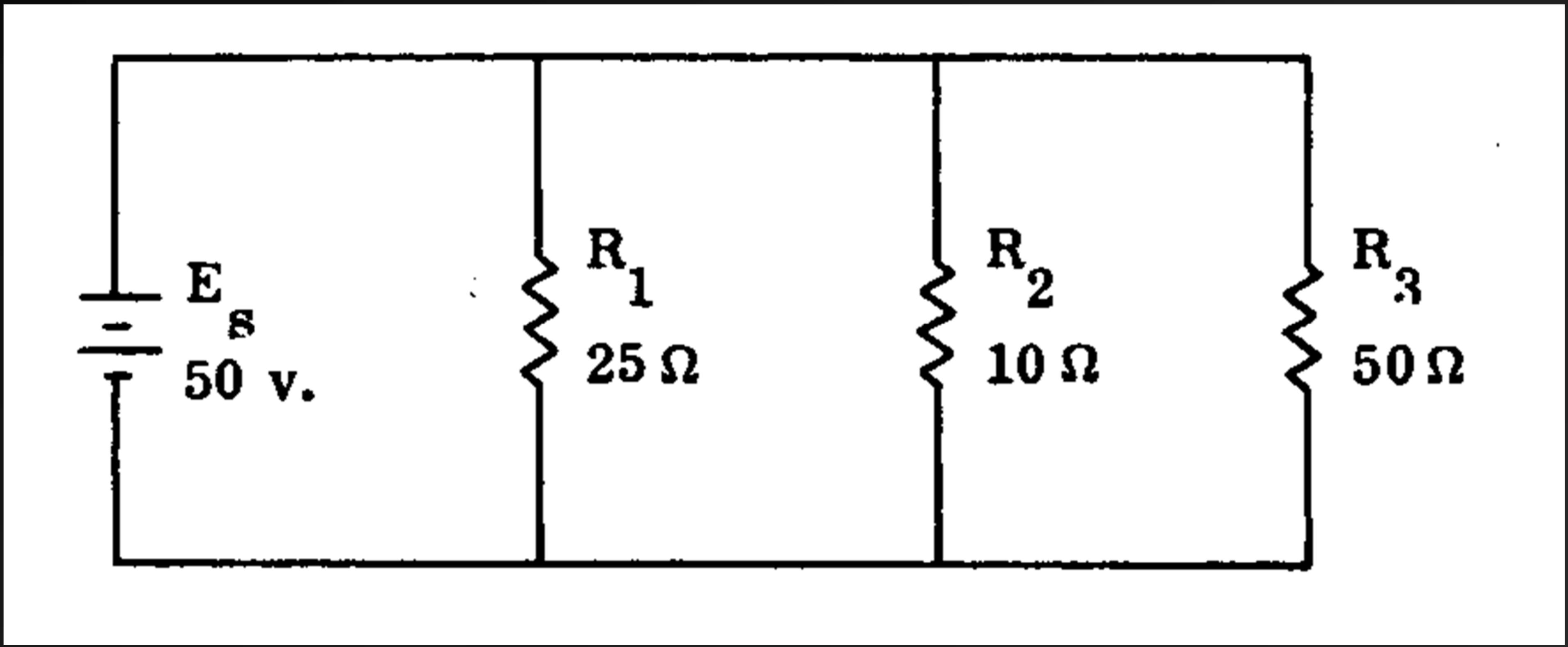
By Analogy: Series Vs Parallel



$$\frac{1}{R_T} = \frac{1}{R_1} + \frac{1}{R_2} + \frac{1}{R_3}$$



Parallel Circuit



$R_T = ?$

$I_T=?$

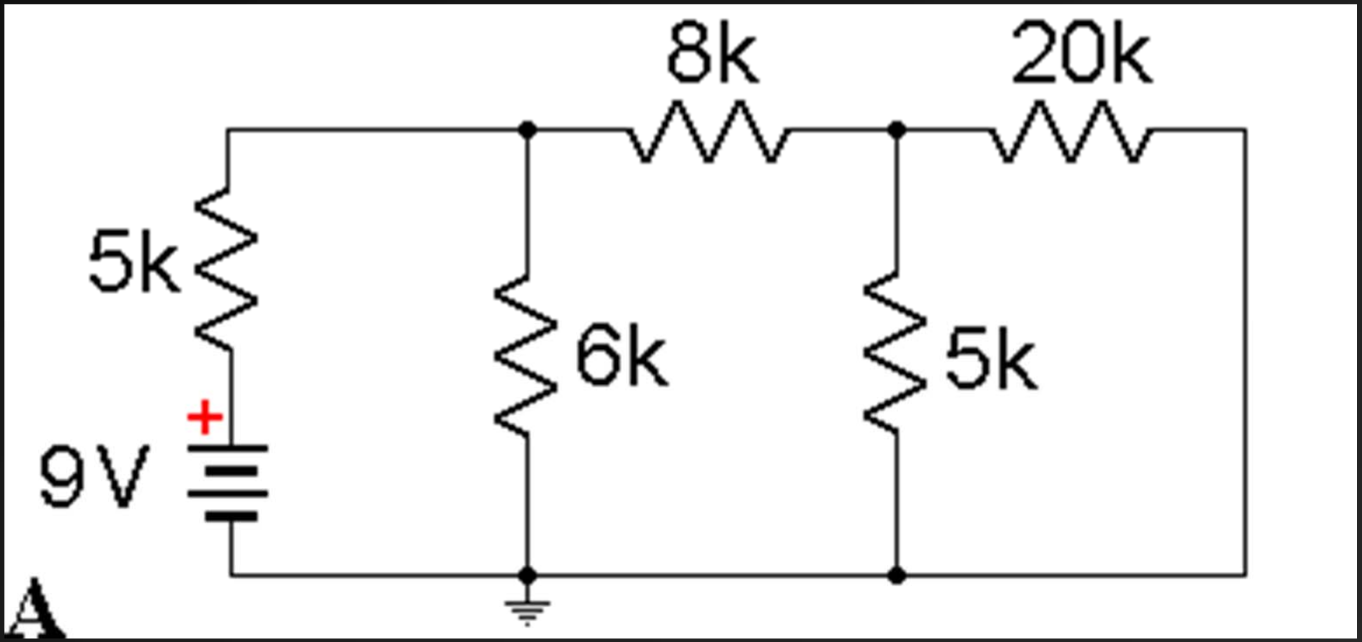
$I_1=?$

$I_2=?$

$I_3=?$

$$\frac{1}{R_T} = \frac{1}{R_1} + \frac{1}{R_2} + \frac{1}{R_3}$$

Complex Circuits

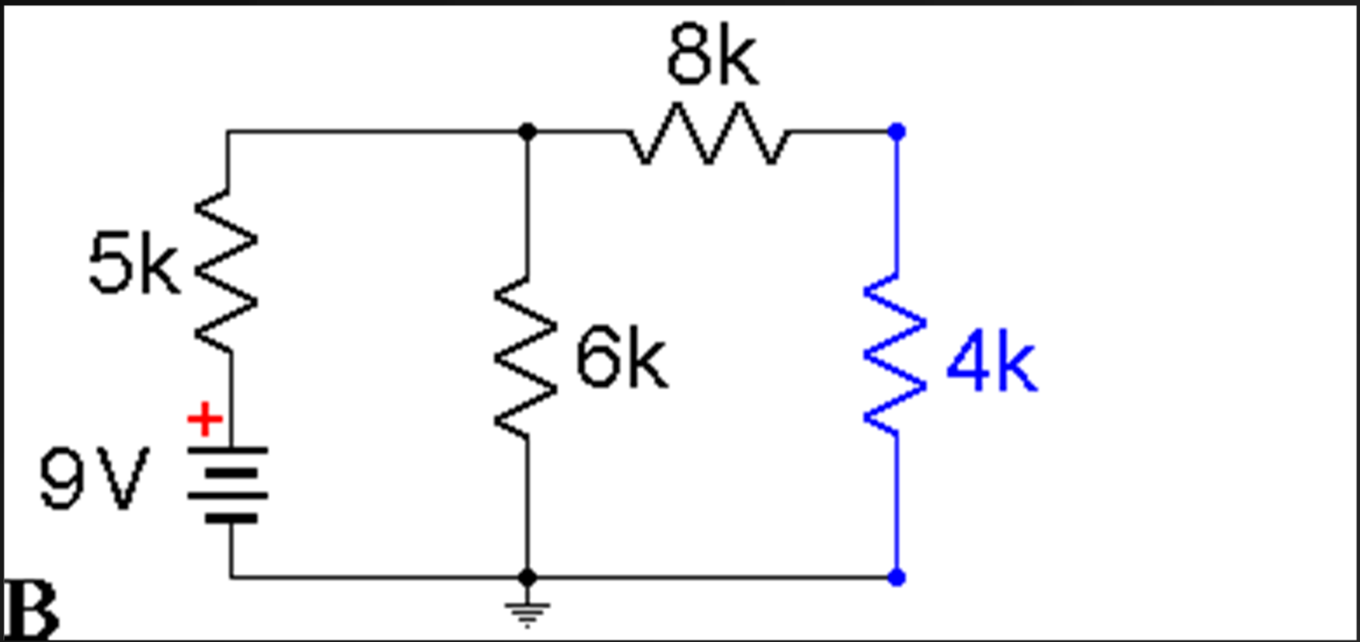


Find the current flowing in the circuit, and the voltage drops.

YIKES! Need to reduce. Start at the parallel combination of 20k and 5k resistors; it is replaced with its effective resistance of 4k
[$1/R_{equiv} = 1/20 + 1/5 = 1/20 + 4/20 = 5/20 = 1/4$].

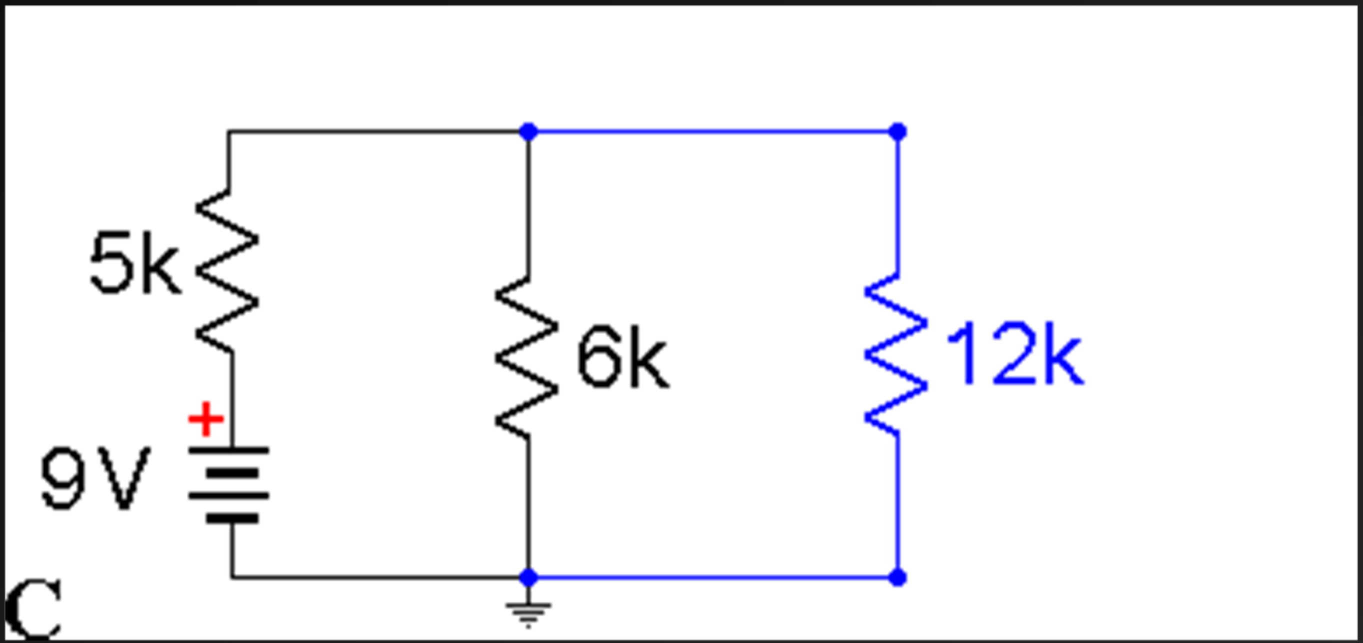
This and subsequent slides on this circuit adapted from:
"http://www.physics.udel.edu/~watson/phys345/examples/effective-circuit.html"

Slightly less Complex Circuit



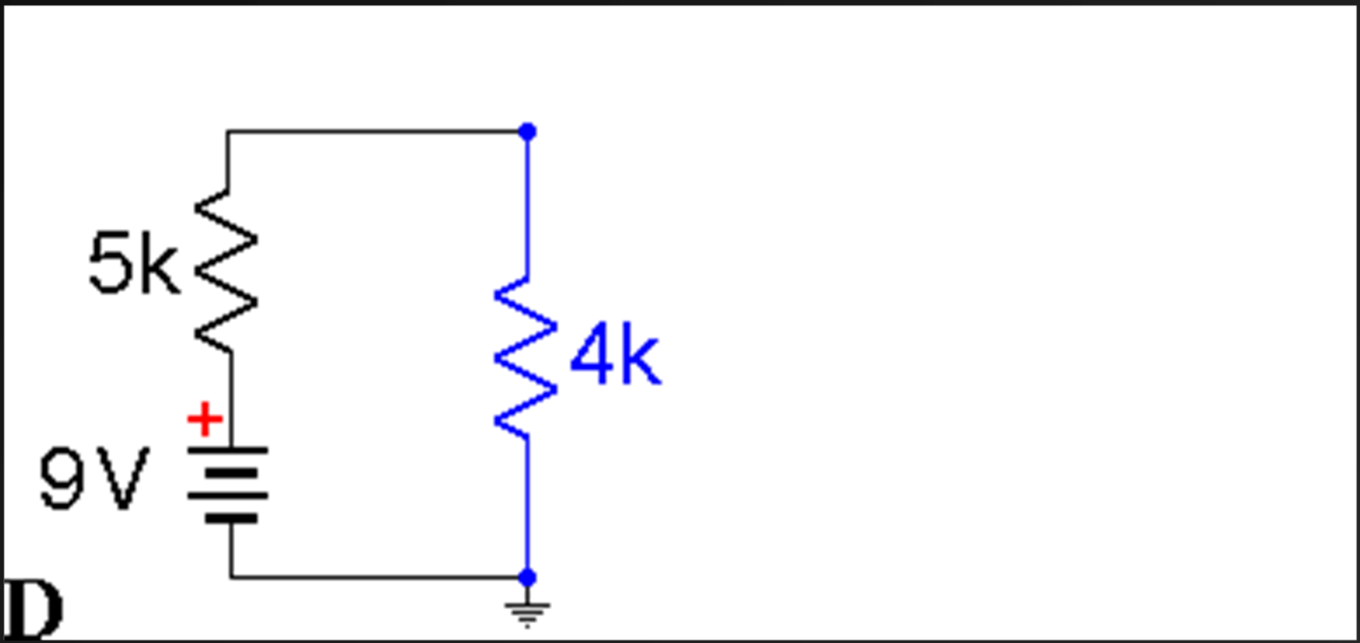
Looking Better. The effective resistance of 4k is in series with the actual resistance of 8k, leading to replacement by its effective resistance of 12k. [R_{equiv} = 4k + 8k]

Less Complex Still



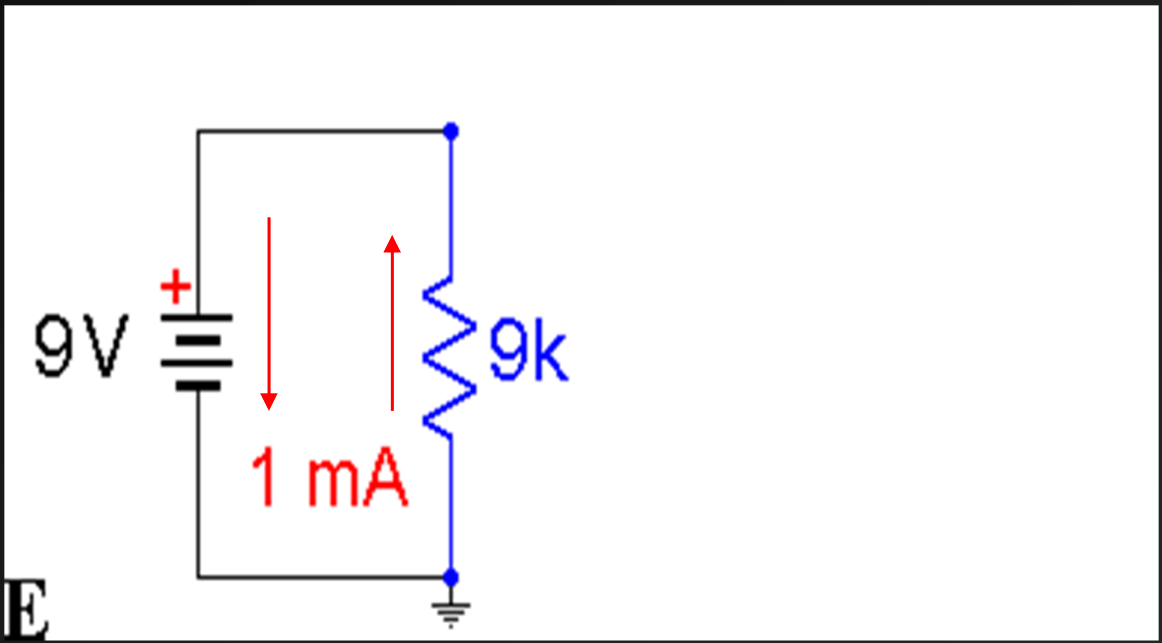
Better Still. Now there is a parallel combination of 12k and 6k resistors; it is replaced with its effective resistance of 4k
[$1/R_{equiv} = 1/12 + 1/6 = 1/12 + 2/12 = 3/12 = 1/4$].

Now Series: Almost Simple



Now we have a simple series circuit!
Finally, the equivalent resistance for the entire circuit is 9k.
[R_{equiv} = 4k + 5k].

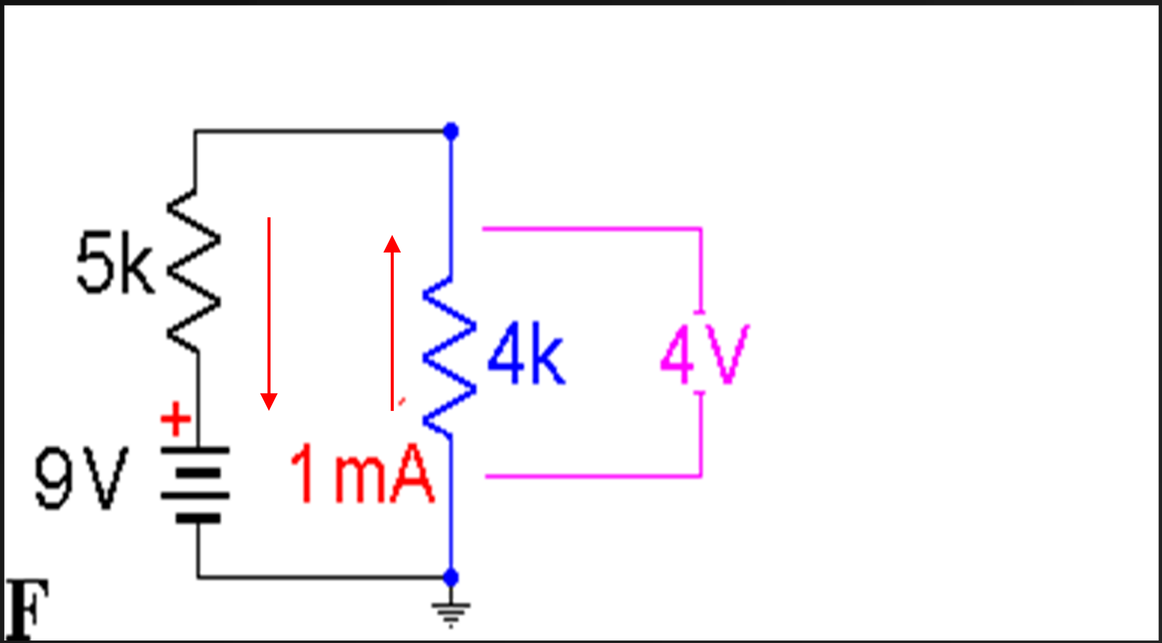
Now Series: Almost Simple



I = ?

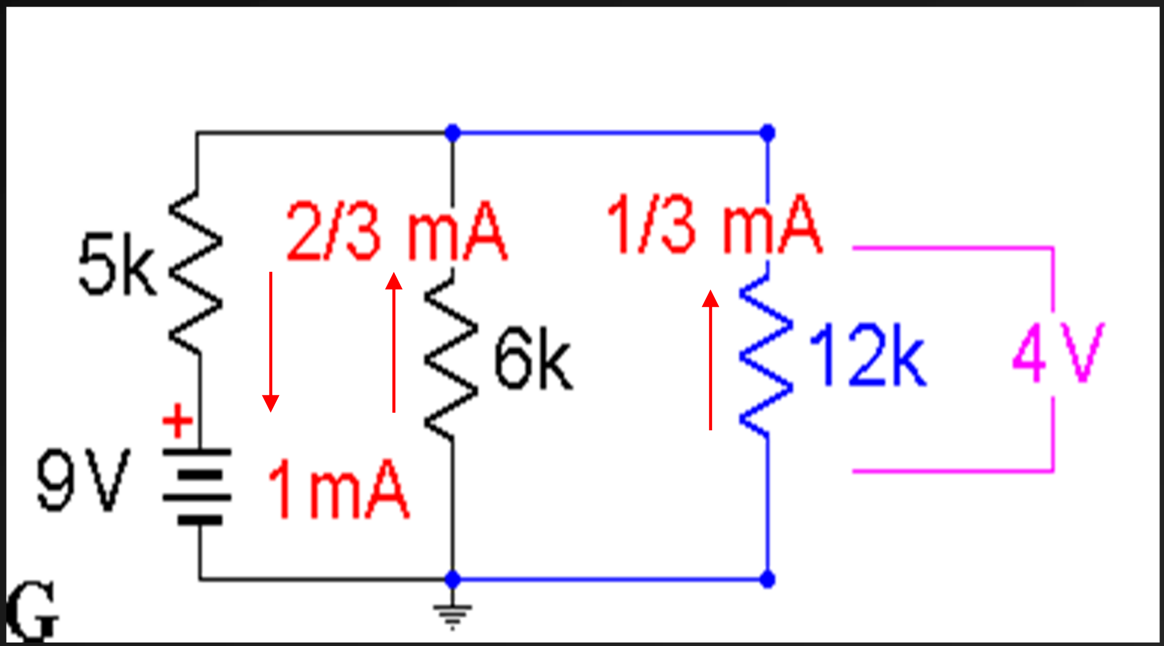
[I = E/R = 9 V/9 k = 1 mA]

Working Back: Voltage Drops and Current



The real 5k resistor and the effective 4k resistance each have 1 mA of current since they are in series. Thus the 4k resistance has 4V of voltage difference across it (by Ohm's law).

Working Back: Voltage Drops and Current

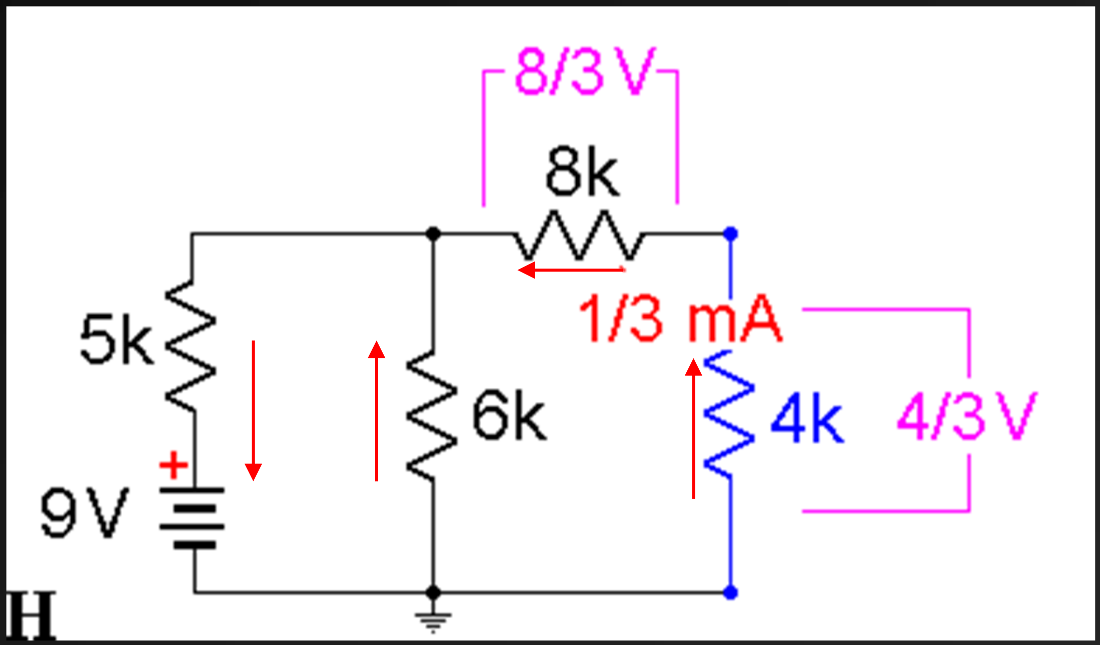


Breaking the 4k resistance into its component parts (in parallel), we find that 2/3 mA of current flows in the 6k resistor and 1/3 mA flows in the effective resistance of 12k.

I = E/R = 4/6K = 2/3 mA

I = E/R = 4/12K = 1/3 mA

Working Back: Voltage Drops and Current

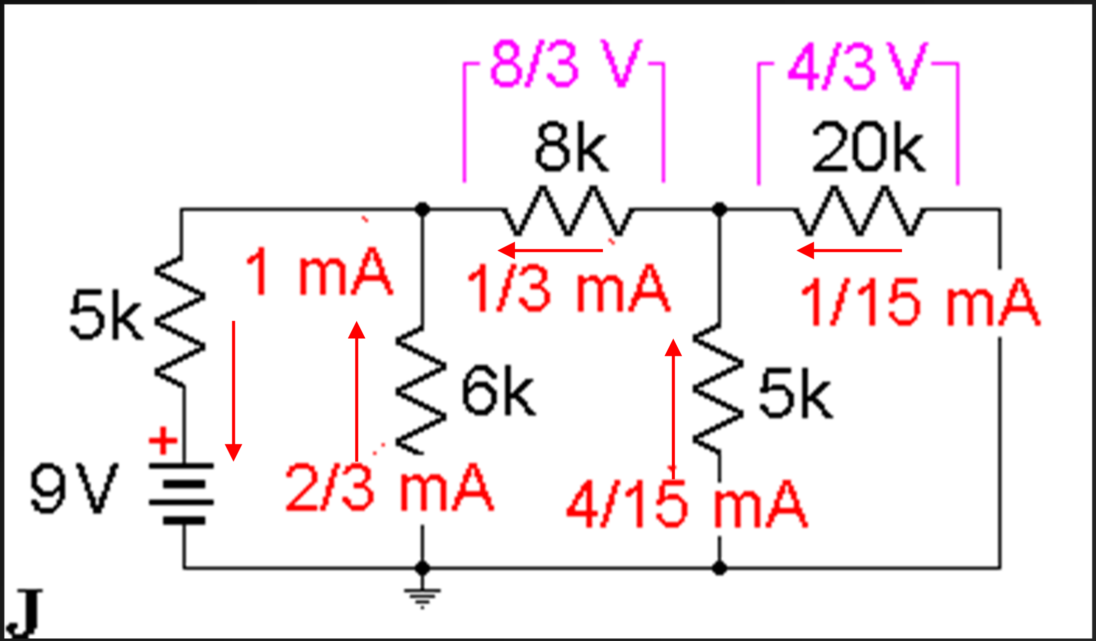


Breaking the 12k resistance into its component parts (in series), we find that there is 8/3 V across the 8k resistor and 4/3 V across the effective resistance of 4k.

$E = IR = 4K\Omega * 1/3\ mA = 4/3\ V$

$E = IR = 8K\Omega * 1/3\ mA = 8/3\ V$

Working Back: Voltage Drops and Current

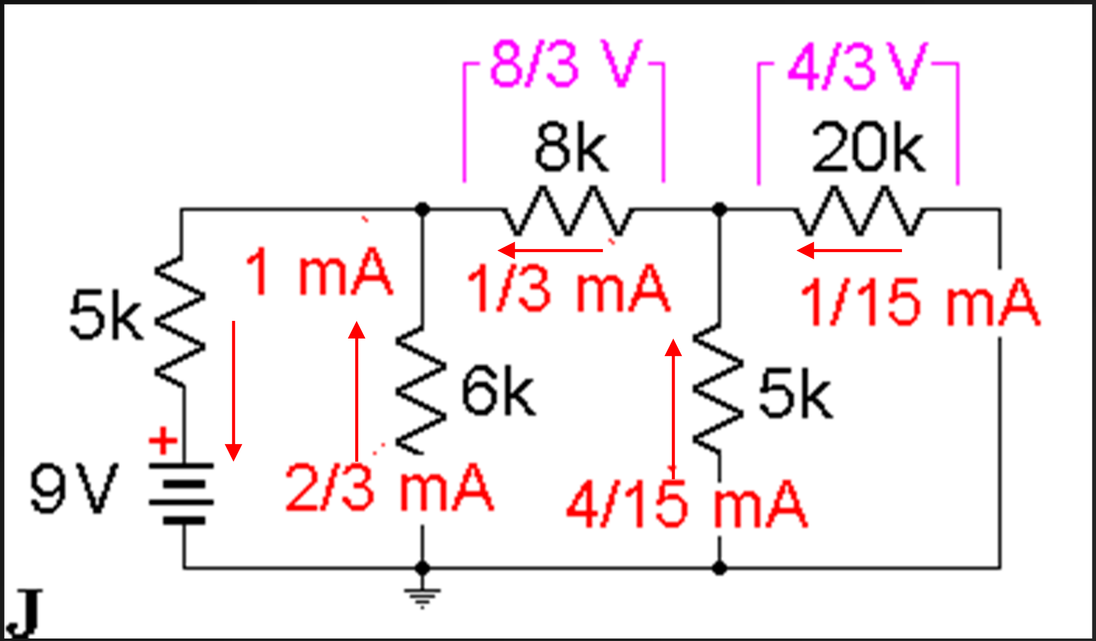


Finally, breaking the 4k resistance into its component parts (in parallel), we find that 1/15 mA of current flows in the 20k resistor and 4/15 mA flows in the 5k resistor.

I = E/R = (4/3V)/20KΩ = 4/60 mA = 1/15 mA

I = E/R = (4/3V)/5KΩ = 4/15 mA

Working Back: Voltage Drops and Current



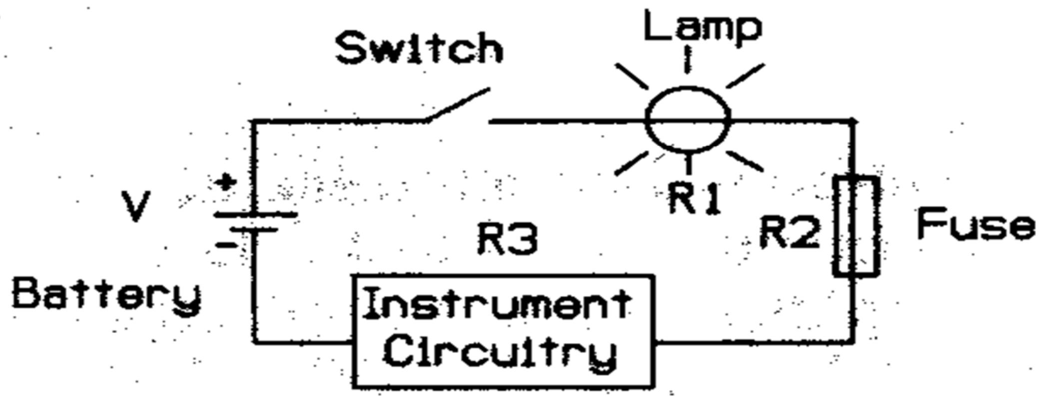
Summarizing:

1. Current through the battery? 1 mA
2. Current through the 8k resistor? 1/3 mA
3. Voltage difference across the 20k resistor? 4/3 V

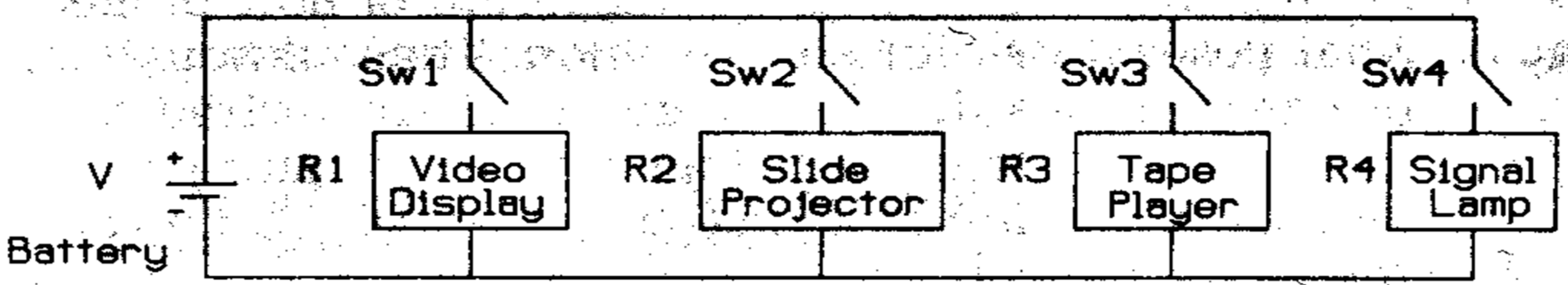
In Real Life…

B. MARSHALL–GOODELL, L. TASSINARY, AND J. CACIOPPO

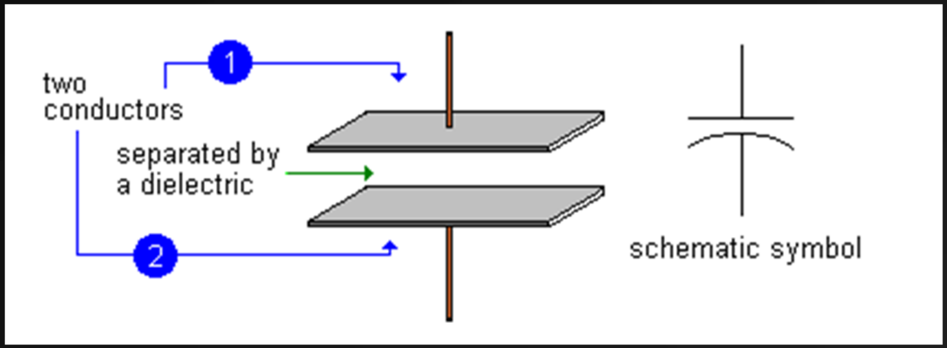
a) Series Circuit

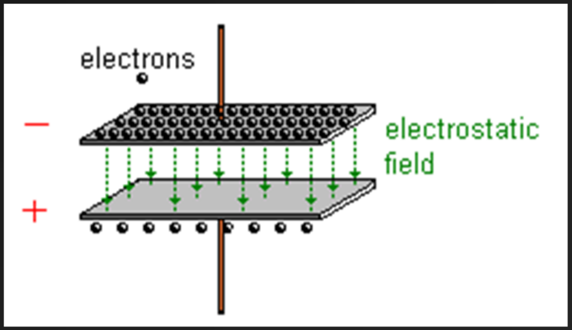


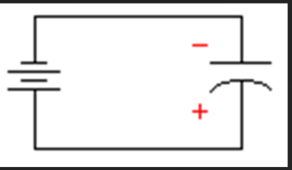
b) Parallel Circuit



Capacitance







Capacitor = two conductors separated by a dielectric.
Dielectric = material that is a good insulator (incapable of passing electrical current), but is capable of passing electrical fields of force. Examples include glass, porcelain.

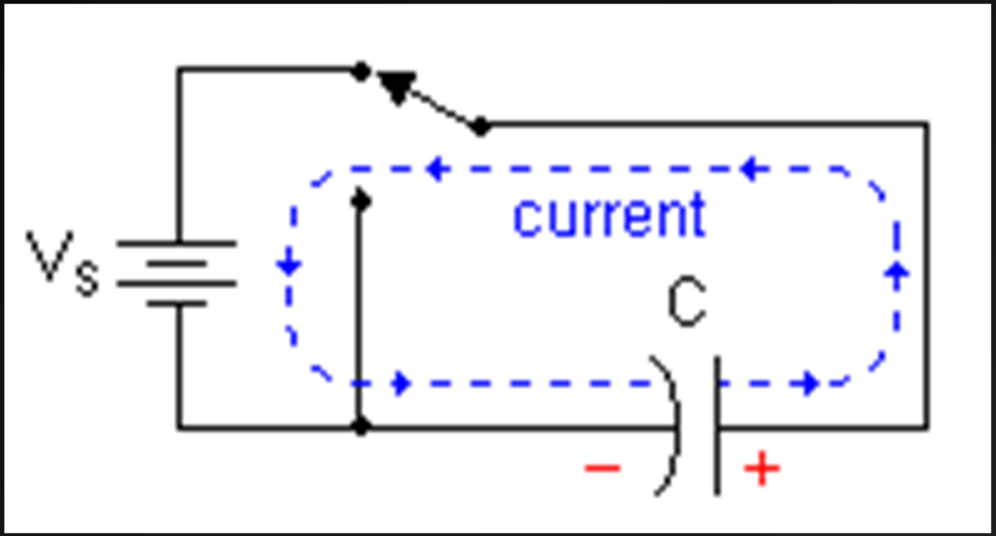
Charged Capacitor = more electrons on one conductor plate than on the other.

Capacitance

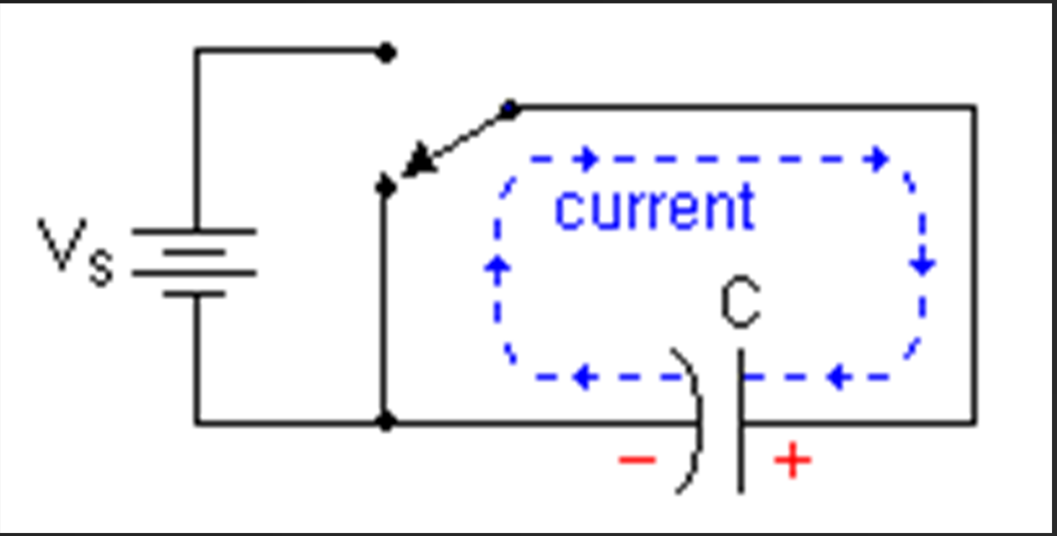
- Two closely spaced plates – offer essentially no resistance

- As negative charge built up on first plate due to flow of electrons, a positive charge would build up on second plate
  - The current **charges** the plates of the capacitor, **but does not flow through the capacitor**, itself.

Capacitance



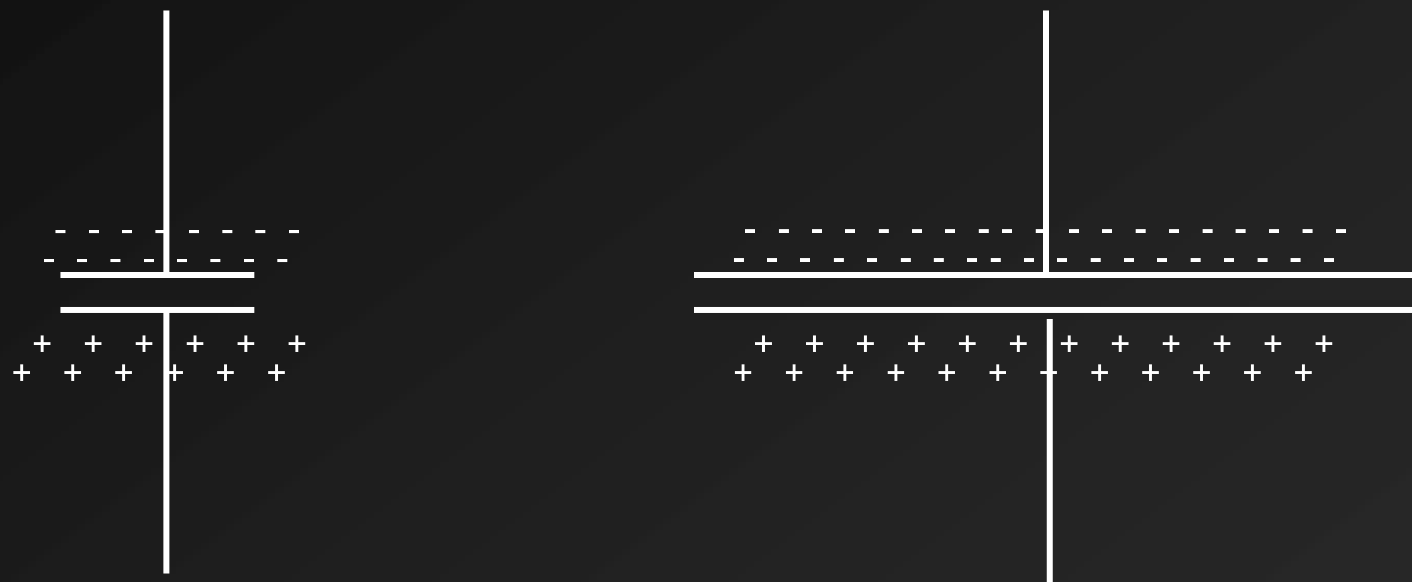
Charging – current flows until capacitor is fully charged, then stops



Discharging – current flows in reverse direction until capacitor fully discharged

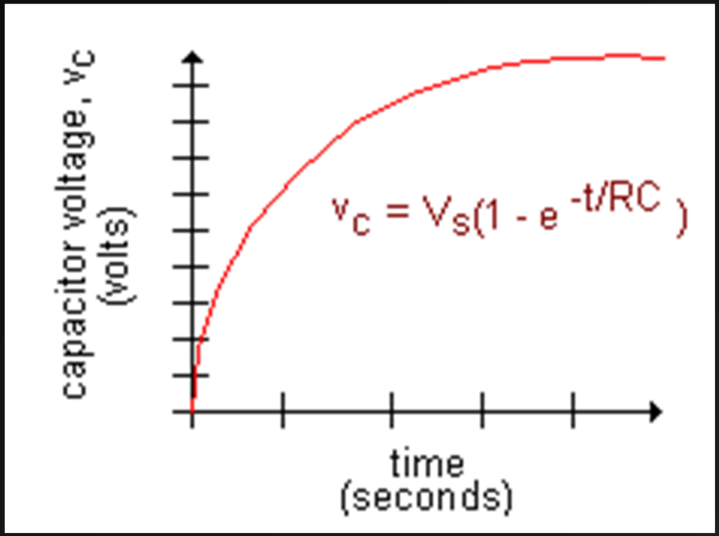
Capacitance – Size Matters

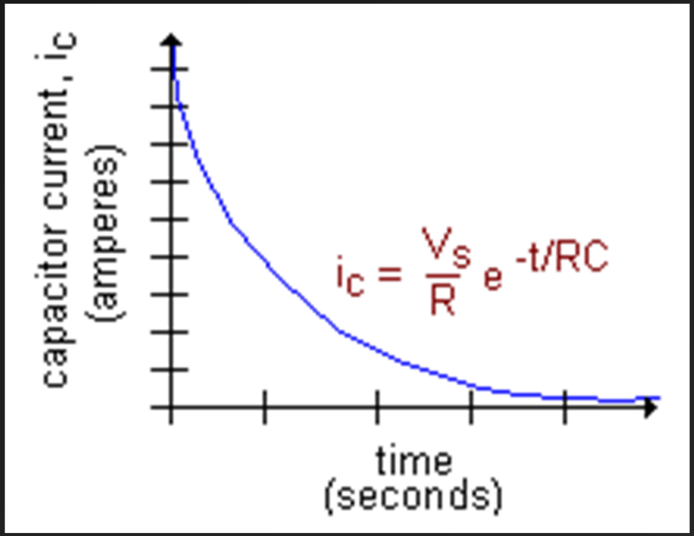
- Which has more capacity?



- More capacity, more current flows before capacitor is fully charged

Capacitor Time Constants





Over time…

Capacitor's voltage increases

Current flow grinds to a halt

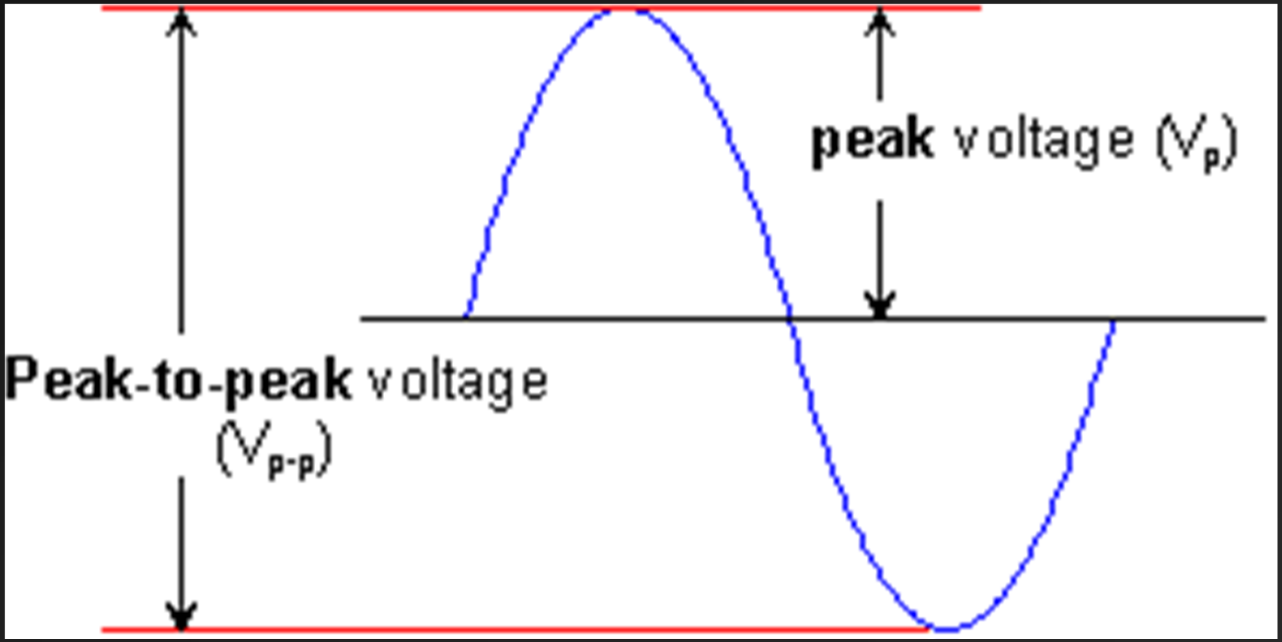
The capacitor's time constant TC=

- The time in seconds for it to become 63.2% charged
- The time in seconds for current flow have slowed by 63.2% from its starting value

AC Circuits


- DC Circuit: Current Flow is unidirectional, from – to +


- AC Circuit: Current Flow switches direction periodically (at a given frequency in Hz)



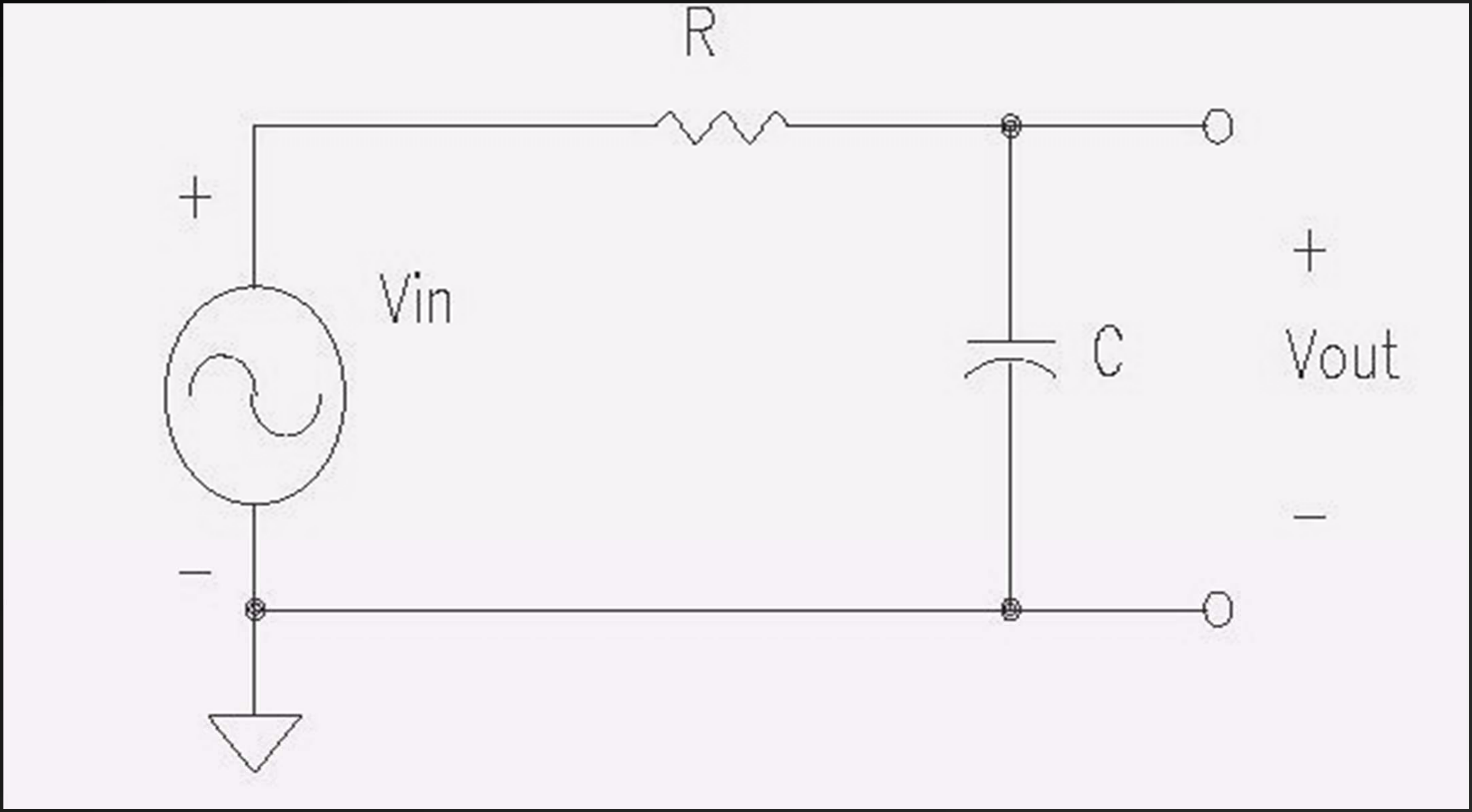
AC Circuits and Capacitance

- Slowly alternating signals
  - will fully charge capacitor, and signal will be impeded
- Rapidly alternating signals
  - will not fully charge the capacitor before the direction of flow reverses, allowing signals to pass unimpeded

http://micro.magnet.fsu.edu/electromag/java/capacitor/

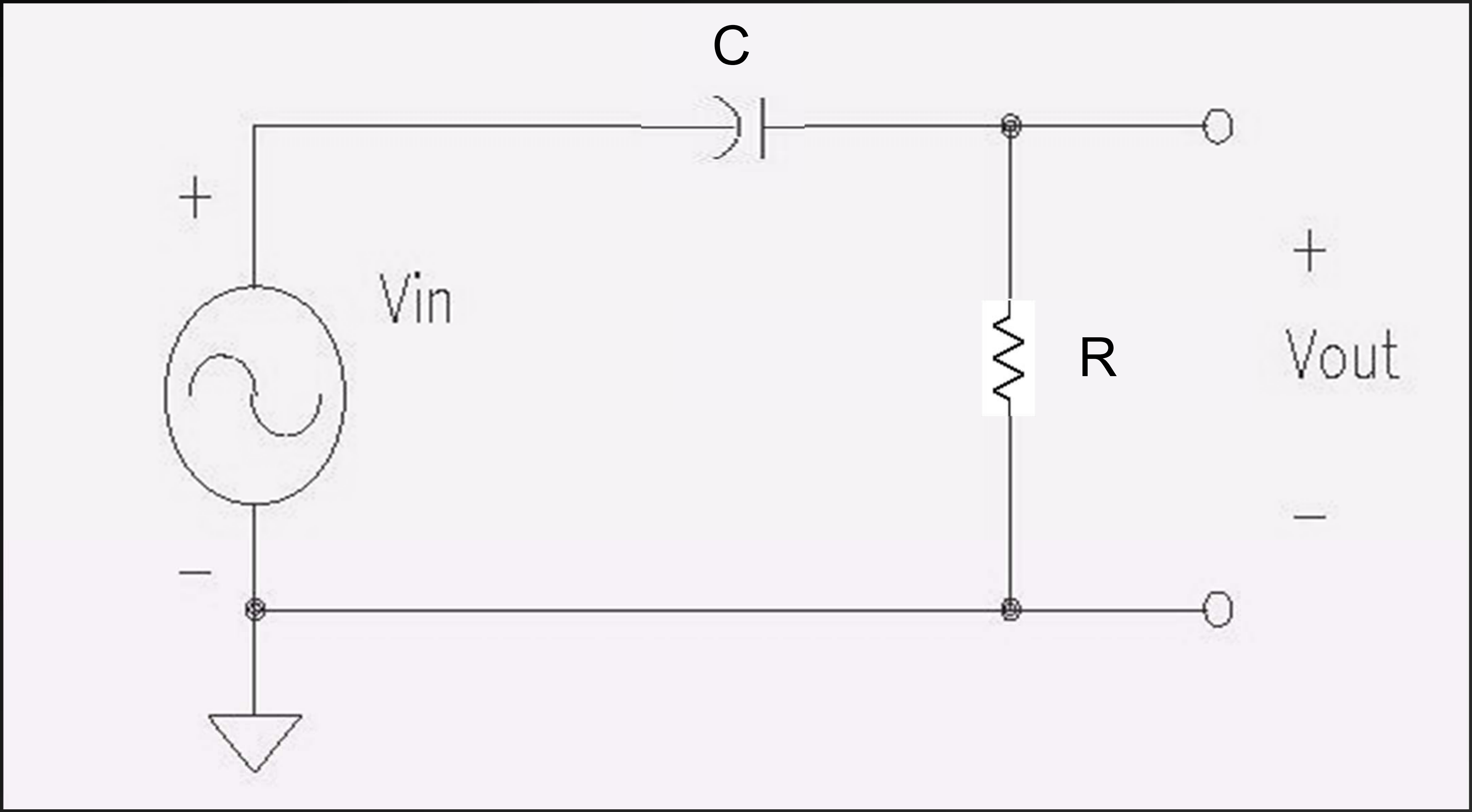
http://www.vjc.moe.edu.sg/academics/dept/physics_dept/applet/rc/rc.htm

Using Capacitors to make Low Pass Filters

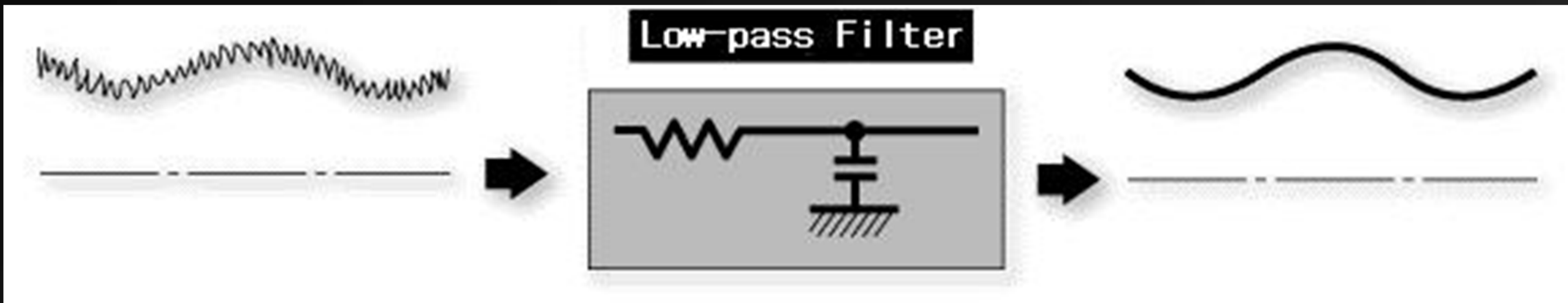


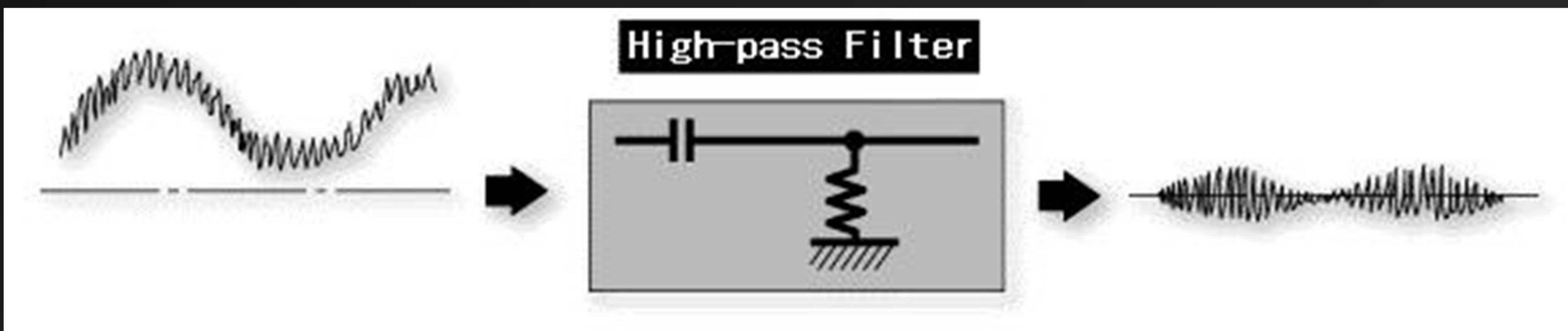
What will happen to fast signals; slow signals?

Using Capacitors to make High Pass Filters



What will happen to fast signals; slow signals?


Low-pass Filter


High-pass Filter