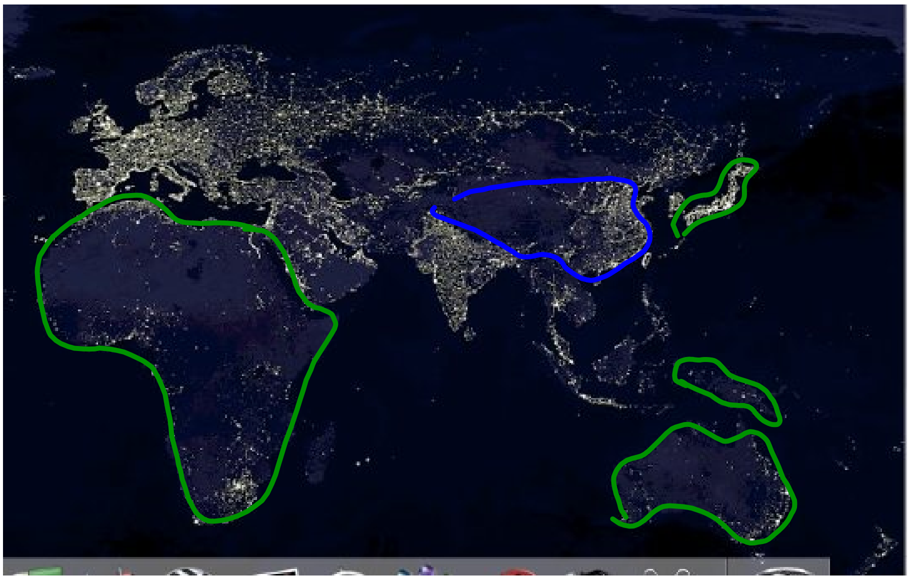
White 18-19
White 20-23

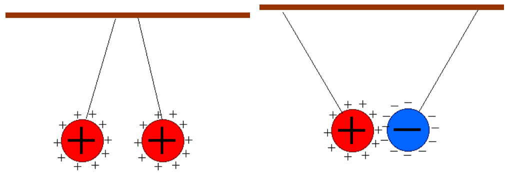
Electricity

Ch 20-23 Green



Charge

- Positive or Negative charge
- Caused by an excess or absence of electrons. Unit is Coulomb (C)
- Like charges repel, opposites attract
- Proportional to the net force
- Electric fields: effect on other charges around it, strength depends on size of charge

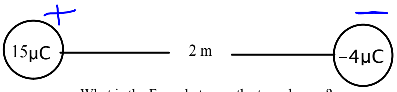


Mass: Electron 9.11 x 10^-31kg Proton&Neutron 1.67x10^-27 kg
Charge: Electron = -1.6 x 10^-19 C Proton 1.6 x 10^-19 C

How many electrons are in 1 Coulomb?

Coulomb's Law Electric Force = k(q1q2/r²)

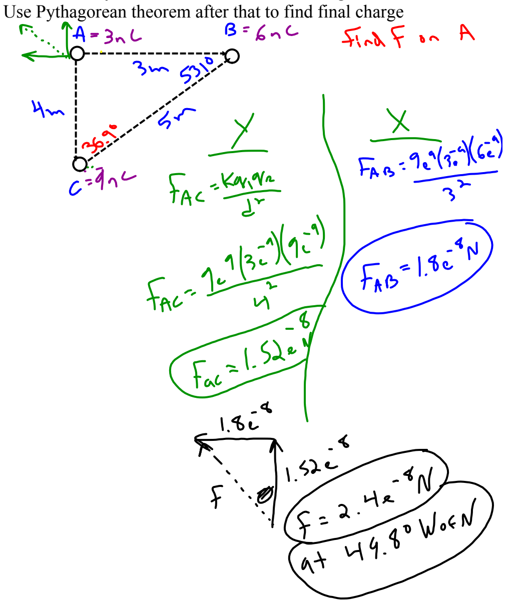
k= 8.99x10^9 Nm²/C²

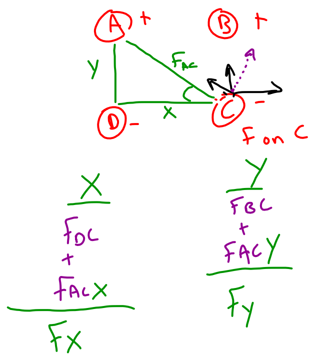


What is the Force between the two charges?

Superposition: use geometry to figure out the charge

1. Solve for the charge in between each one first
2. Use Fx cos Fy sin for the one that is at an angle
3. Use Pythagorean theorem after that to find final charge



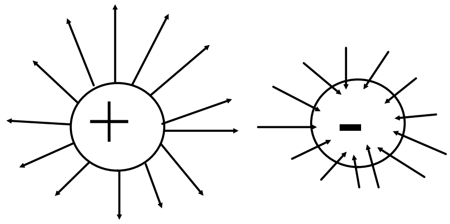


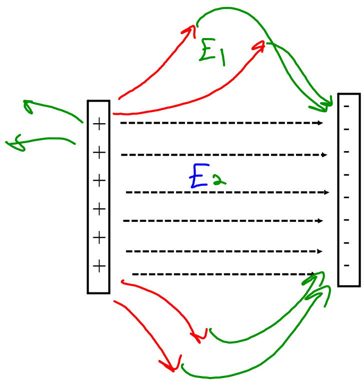
- Electric Field strength $E = F/q_1$

The charge that the field is around

$E = \frac{kq}{r^2}$ $E = F/q$ unit = N/C

Electric field lines go out of the positive charge and into the negative charge

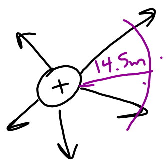




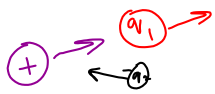
$E = .15\ N/C$
$q = 3.5\ nC$
$F = ?$
$r = ?$

$E = F/q$
$.15 = F/3.5e^{-9}$
$F = 5.25e^{-10}\ N$

$E = \frac{kq}{r^2}$ $.15 = \frac{9e^{9}(3.5e^{-9})}{r^2}$
$r = 14.5m$

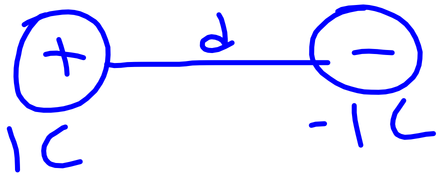


$E = 2\ N/C$
$q_1 = 18e^{-8}\ C$
$q_2 = -24e^{-8}\ C$
$F_1 = ?$
$F_2 = ?$

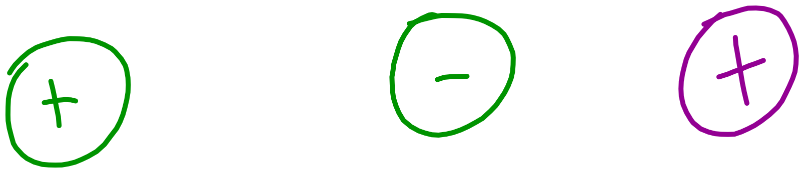


$F_1 = 3.6e^{-7}\ N$
$F_2 = -4.8e^{-7}\ N$

Electric Dipole



http://hyperphysics.phy-astr.gsu.edu/hbase/electric/dipole.html#c1



Equilibrium- set the charges equal to one another and find the distance the new charge has to be placed inbetween them

$F_{2,3}=kq_2q_3/p_{2,3}{}^2 = F_{3,1}=kq_3q_1/(d-l_{3,1})^2$

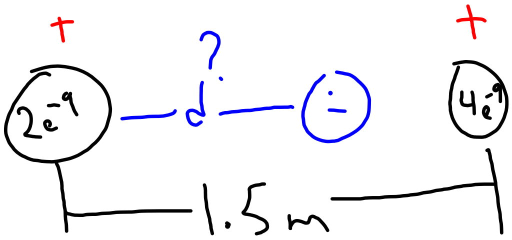
L = total Length A + C

$q_1/d^2 = q_2/(L-d)^2$

Equilibrium $\frac{q_1}{d^2} = \frac{q_2}{(L-d)^2}$

$q_1 = 2e^{-9}$ C

$q_2 = 4e^{-9}$ C



$\frac{q_1}{d^2} = \frac{q_2}{(L-d)^2}$

$q_1 = 15e^{-6}$ C

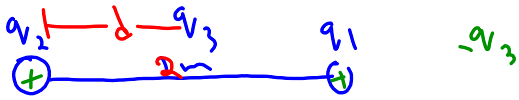
$q_2 = 6e^{-6}$ C

$q_3 = (-)$

$\Sigma F = 0$

L = 2 m

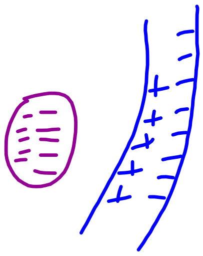
d = ?



$\frac{q_1}{d^2} = \frac{q_2}{(L-d)^2}$

You will get 2 answers, you must determine which one makes sense for the setup.

Static Charge



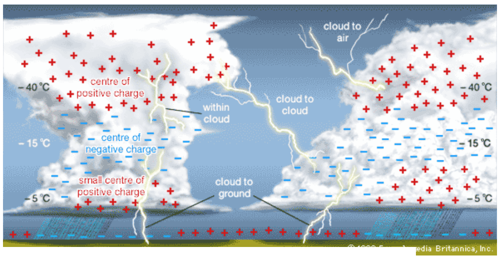
- How charge is transferred between objects
- By contact, friction, induction
- Always conserved in a system
- <u>Friction</u>: balloon and hair, feet on a rug
- Some Atoms lose electrons easier than others
- <u>Contact</u>: charge moves through an object
- <u>Induction</u>: transfer with out contact because of repulsion

edison

electric man

Static Discharge

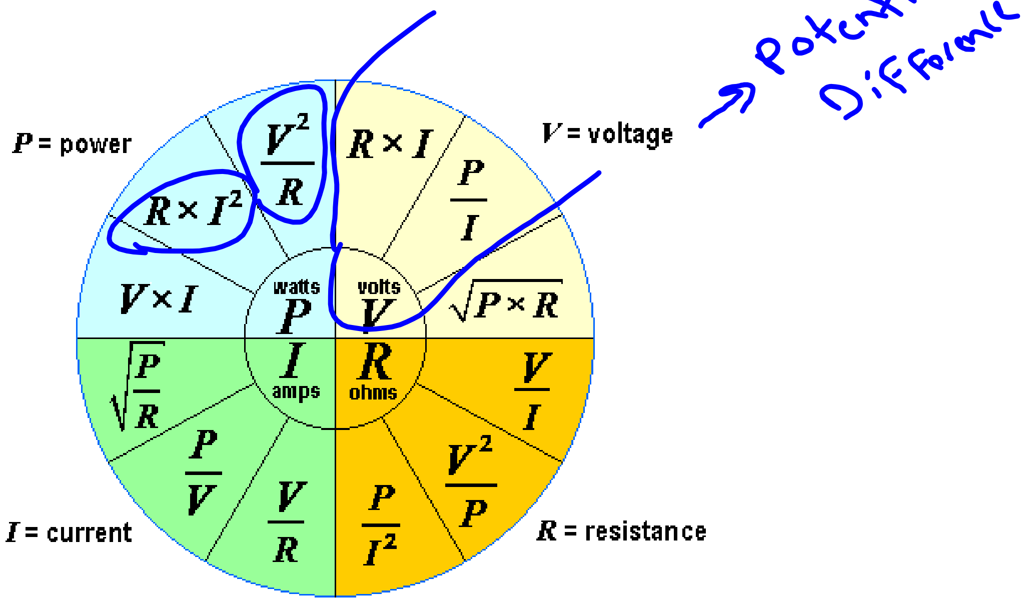
- A pathway suddenly forms for charge to move
- Lightning bolt, a spark, a bolt



Ohm's Law

21-22

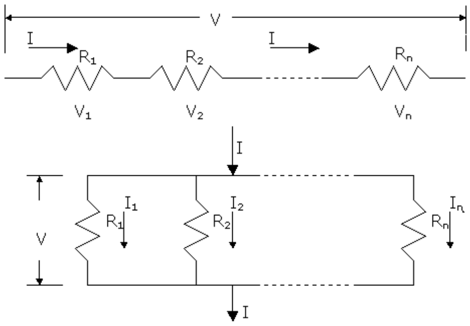
V = IR
P = IV



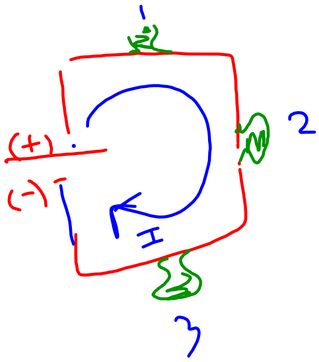
Current (A) ~~symbol (V)~~ Symbol (I)

- Continuous flow of electron, unit is ampere (A)
- Direct Current (DC) flows in one direction
- Alternating Current (AC) flow regularly reverses direction
- $I = \Delta q / \Delta t$
- Electrons move but in a diagram we should it as positives moving

$I = q / Time$



Series and parallel arrangements of resistors



doorknob current

$q = 3\ C$

$T = 10\ s$

$I = ?$

$I = .30\ A$

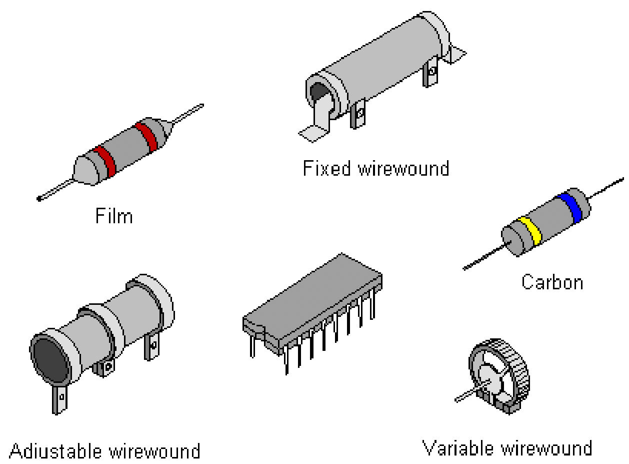
Amps can kill

- .001 A tingles
- .005 A small shock
- .030 A painful, lose muscle control
- .100 A extreme pain, stop breathing
- 1.00 A nerve damage, heart stop, death
- 10.0 A severe burns, death is certain

Resistance (Ω)

Symbol R

- Electrons have collisions with other electrons and ions and release thermal energy
- ✱ Resistance- opposition to flow of electrons, unit is Ohms (Ω)
- Thickness, length, temperature affect resistance
- ✱ Superconductor- near zero resistance



$R = \rho \frac{L}{A}$

Resitance measured in Ohms

R=pL/A

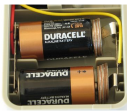
ρ = resistivity of material

Green

chart on pg 721

Voltage (V) → EmF

- Potential difference- difference in electrical potential energy between 2 places in an electric field, unit is voltage (V)
- Sources- batteries, solar cells, generators
- Battery: converts chemical energy into electric energy



$U_E = qV = \left(\frac{1}{4\pi\epsilon_0}\right)\left(\frac{q_1 q_2}{r}\right)$

EPE= qV

U_E $\qquad U_E = K\frac{q_1 q_2}{r}$

- E=Pt Energy = Power x time
- Energy unit is kilowatt hours1kwh= 3,600,000j

$U = K\frac{q_1 q_2}{r}$

$U_E = PT$

Potential difference on a point charge

V=kq/r $\qquad V = \frac{1}{4\pi\epsilon_0}\Sigma\left(\frac{q}{r}\right) \qquad V = K\frac{q}{r}$

combining Electric field and Potential $\qquad V = K\left(\frac{q_1}{r_1} + \frac{q_2}{r_2} + \frac{q_3}{r_3}\right)$

E=-V/d $\qquad E = \frac{\Delta V}{d}$

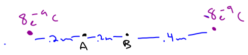
Gauss' Law E = q/ o A

$q = 4e^{-8}C \qquad V = \frac{Kq}{r}$

$r = 1.2m$

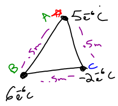
$V = ? \qquad V = \frac{9e^9(4e^{-8})}{1.2}$

$V = 300V$



$V_A = ?$

$V_B = ?$



$V_A = 9e^9\left(\frac{-2e^{-6}}{.5} + \frac{6e^{-6}}{.5}\right)$

$V_A = 72,000V$

$V_B = 9e^9\left(\frac{-2e^{-6}}{.5} + \frac{5e^{-6}}{.5}\right)$

$V_B = 54,000V$

$V_C = 9e^9\left(\frac{6e^{-6}}{.5} + \frac{5e^{-6}}{.5}\right)$

$V_C = 198,000V$

$U_T = ?$

$U = qV$

$U = qV$

$U_A = 5e^{-6}(72,000)$

$U_A = .36J$

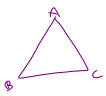
$U_B = 6e^{-6}(54000)$

$U_B = .324J$

$V_C = -.396J$

$U_T = U_A + U_B + U_C$

$U_T = .288J$



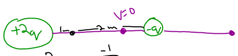
$U_T = U_{AB} + U_{BC} + U_{AC}$

$V_{AC} = \frac{Kq_A}{r}$

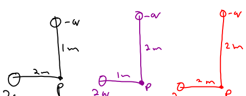
$U_{AC} = q_C V$

$V_{AB} = \frac{Kq_A}{r}$

$U_{AB} = q_B V$



$\frac{2}{2} \qquad \frac{-1}{1}$



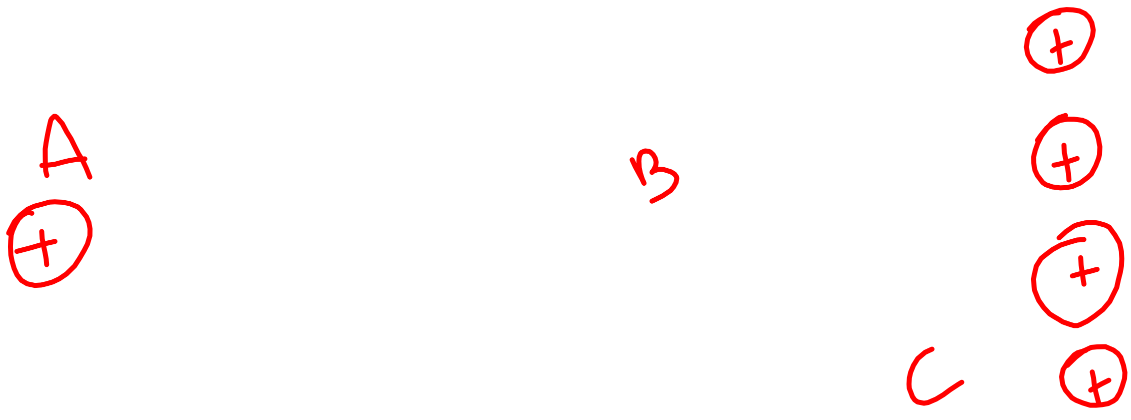
$\frac{2}{2} + \frac{-1}{1} \qquad \frac{2}{1} + \frac{-1}{2} \qquad \frac{2}{2} + \frac{-1}{2}$

0 V. $\qquad$ 1.5V $\qquad$ .5V

$V_A = 108V$
$V_B = 36V$

$U_A =$
$U_B =$

A charge's electric potential energy at any point is equal to the amount of work done in moving it there from is rest position.



$q_1 = 15nC$

$V_A = 300V$

$V_B = -200V$

$U_E = ?$

$\Delta V = ?$

$r = .01m$

$V = ?$

$q = 1nC$

.

Parallel plate capacitors- store charge. Have the same magnitude of opposite charge on two conductors with a separation between them.

unit F (f)
Farad

$C = q/V$

$C = \frac{q}{V}$

$C = \epsilon_o A/d$
Parallel Plates

$C = \frac{K \epsilon_o A}{d}$

$\epsilon_o = 8.85e^{-12} \frac{C^2}{Nm^2}$

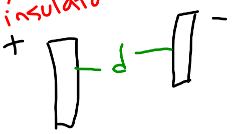
A → area

d → between plates

dielectric constant for insulator

$U_c = 1/2\ QV = 1/2\ CV^2$

$E_c = q/\ \ o\ A$



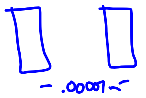
$K_{vac} \Rightarrow 1$

$K_{air} \Rightarrow 1.00054 \approx 1$

$K_{Teflon} \Rightarrow 2$

C = 1.3 μF
V = 1.5 v
q = ?

C = 1 μF
d = .07 mm = .00007 m
A = ?



V = 1.5 V
q = ?

$U_c = \frac{1}{2} CV$

C = 220 μF
V = 330 v
U_c = ?
T = 1 ms
P = ?

U = PT

$d_1 = 5e^{-3}$ m

$d_2 = .15e^{-3}$ m

$A = 9.5e^{-5}$ m^2

$K = 3.5$

$\Delta C = ?$

$C_{final} - C_{Initial}$

$$C = \frac{K \varepsilon_0 A}{D}$$

$V_1 = 100V$

$V_2 = 30V$

$$E = \frac{V_c}{d}$$

$C = 150$ mF

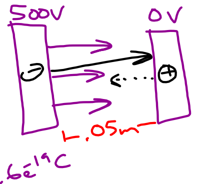
$V = 2000V$

$d = .01$ mm

$K = 300$

$A = ?$

$U_c = ?$



$e^- = 1.6e^{-19}$ C

$d = .05$ m

$v_f = ?$

$v_i = 0$ m/s

$U_c = ?$

Ch 20: 5,9,15,20,23,24,27,29

problems 4,9,10,16,18,24,26,30,48,49

Ch 21: 2,7,18,23,24,25,28,30

problems
2,6,12,16,22,27,28,31,36,37,39,42,59,65

Ohm's Law

- V=IR
- Voltage = Current x Resistance

$V = IR$

Power

$P = IV$

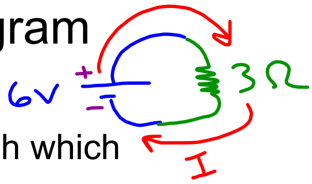
$P = I^2R$

$P = V^2/R$

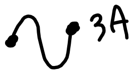
- P=IVPower = Current x Voltage
- Power unit is watts
- $P=V^2/R$ $P=I^2R$ $P=IV$

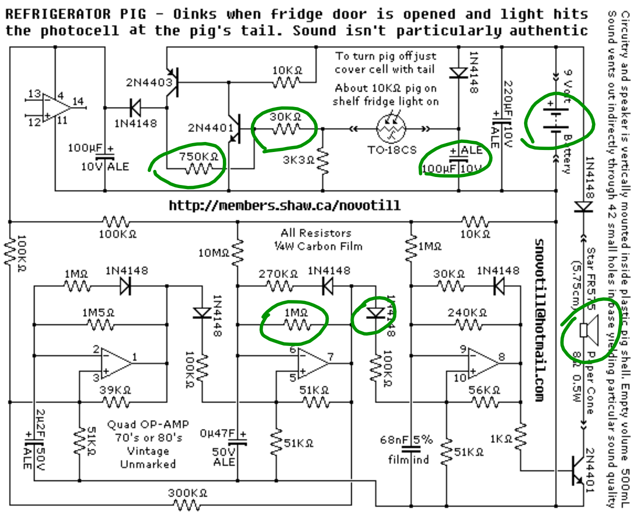
$EE = Pt$

Circuit Diagram



- Circuit- a complete path through which charge can flow
- Use symbols
- Battery
- Resistor
- Current direction I
- Voltage 120V
- Capacitor 6F
- Fuse



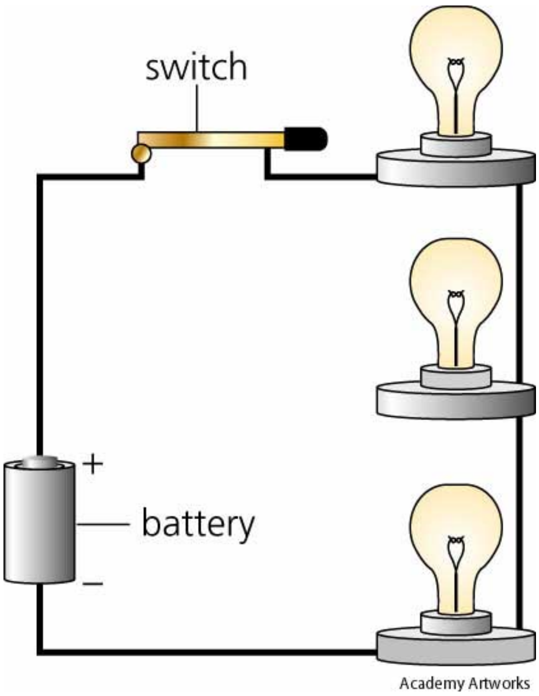


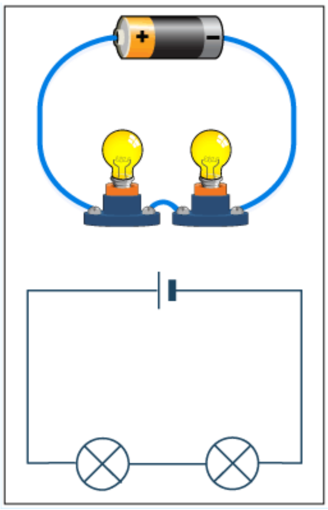
http://www.kpsec.freeuk.com/symbol.htm

http://talkingelectronics.com/CctSymbols/Circuit_Symbols.html

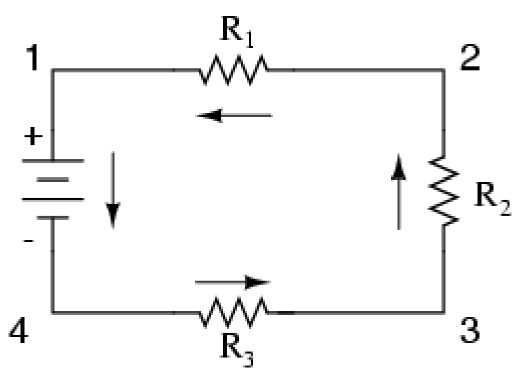
2 Types of Circuit

- Series: only one path to follow, a circle
- If chain is broken everything stops moving and working
- Adding bulbs to a series increases the resistance, so every bulb is less bright because it gets less current
- To find V,I,R across a resistor you must first find R Total, I total, V total
- $R_{total} = R_1 + R_2 + R_3 + ...$
- Current stays the same across all resistors
- Voltage Changes at each resistor





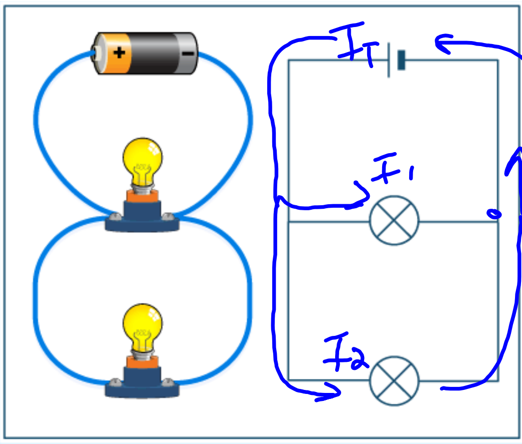
Series

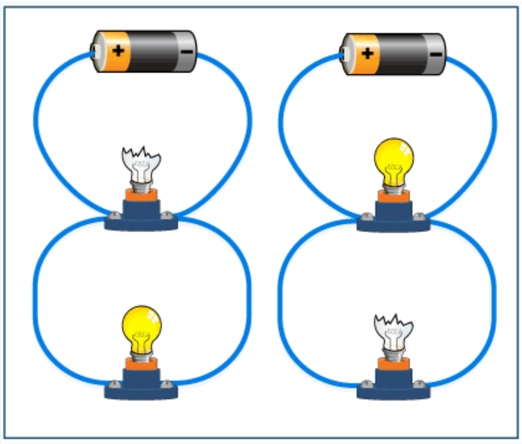


Parallel Circuit

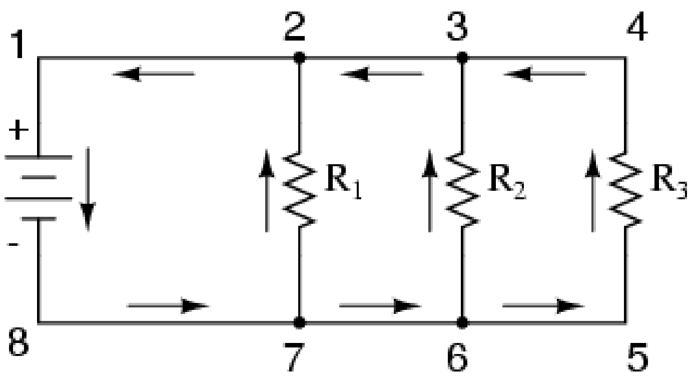
- 2 or more possible path for charge to follow
- If one chain is broke the current will continue to follow the other paths
- This is how homes are wired
- $R_{total} = 1/R_1 + 1/R_2 + 1/R_3 + ...$
- Current changes across each resistor
- Add up to I Total
- Voltage same across each resistor

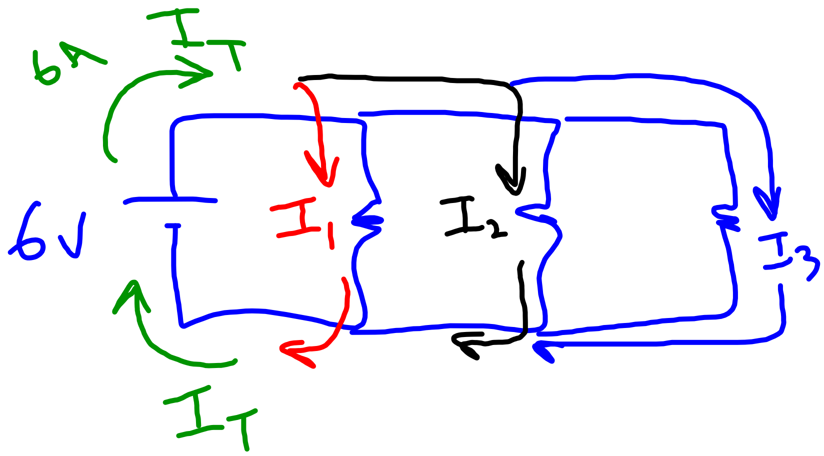
$$\frac{1}{R_T} = \frac{1}{R_1} + \frac{1}{R_2} + \dots$$





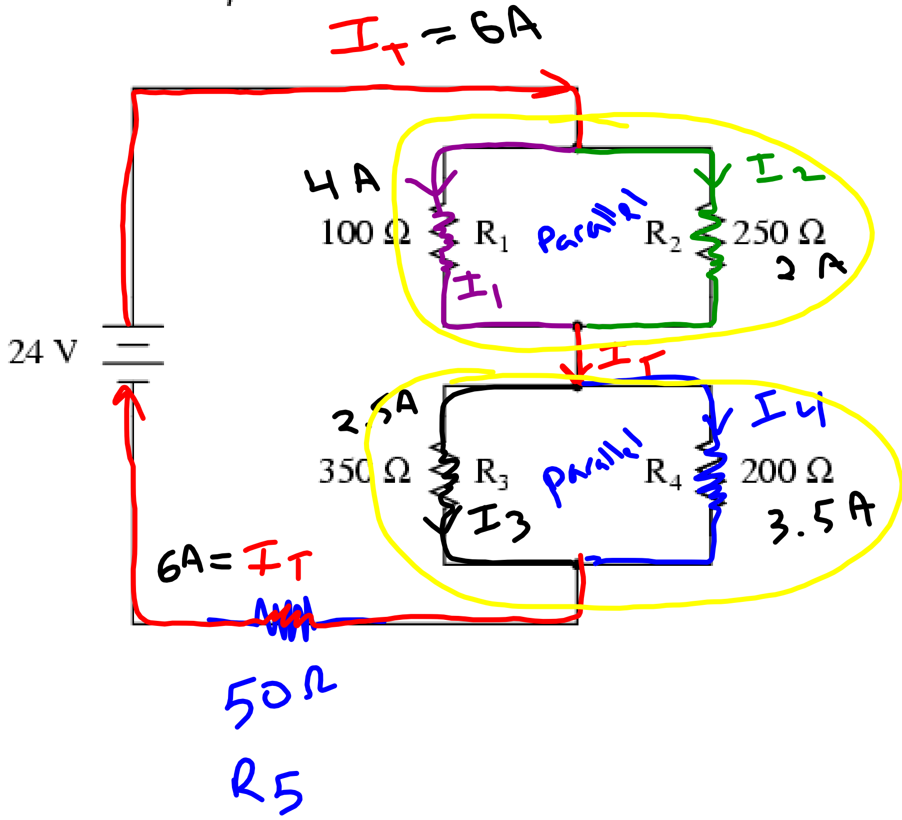
Parallel

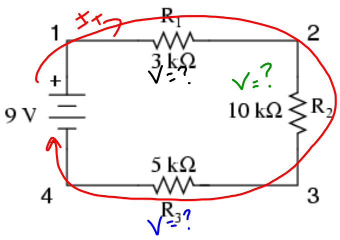



6A
I_T
6V
I_1
I_2
I_3
I_T

- Combination Circuit
- You can have combination of series and parallel circuits in one large circuit
- Reduce it down to make 1 simple circuit

A series-parallel combination circuit





V=IR

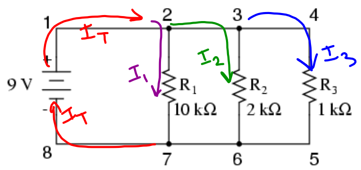
$V_1 = .0005(3000)$

$V_2 = .0005(10,000)$

$V_3 = .0005(5000)$

V	I	R	P
1.5V	.0005	3000 Ω	
5V	.0005	10,000 Ω	
2.5V	.0005	5,000 Ω	

V_t= 9V



V=IR

9=I(10,000)

V=IR

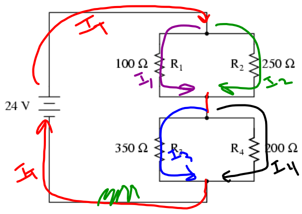
9=I(2000)

$9=I_3(1000)$

V	I	R	P
9V	.0009A	10,000 Ω	
9V	.0045A	2,000 Ω	
9V	.009A	1,000 Ω	

V_t= 9V I_t= A

A series-parallel combination circuit



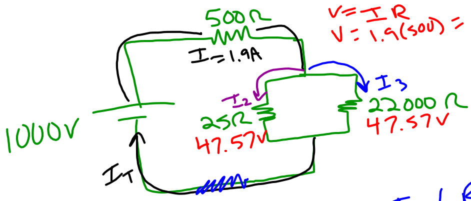
$I_1+I_2=I_T$

$I_{12}=.121A$

$I_3+I_4= .121A$

V	I	R	P
8.63	.08637	100 Ω	
8.63	.03452	250 Ω	
15.4	.044	350 Ω	
15.4	.077	200 Ω	

V_t= 24V



V=IR

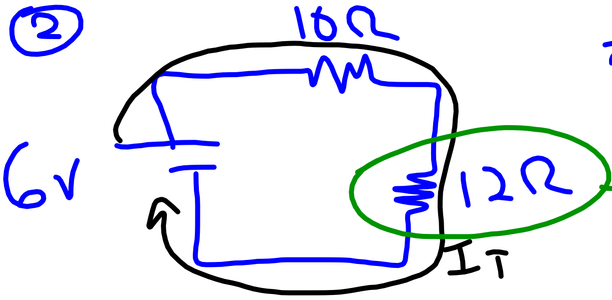
V = 1.9(500) = 952.43V

$V_T = V_1 + V_2$

$1000 = 952.43 + V_2$

V	I	R
952.43	1.9A	500Ω
47.57	1.89A	25Ω
47.57	.002A	22000Ω

(2)



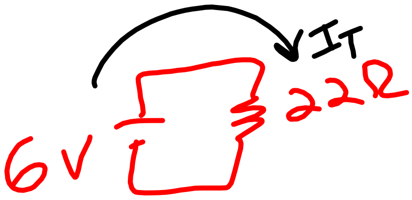
$\frac{1}{20} + \frac{1}{30} = \frac{1}{R}$

$V = IR$

$V = .27(12)$

$V = 3.25V$

(3)

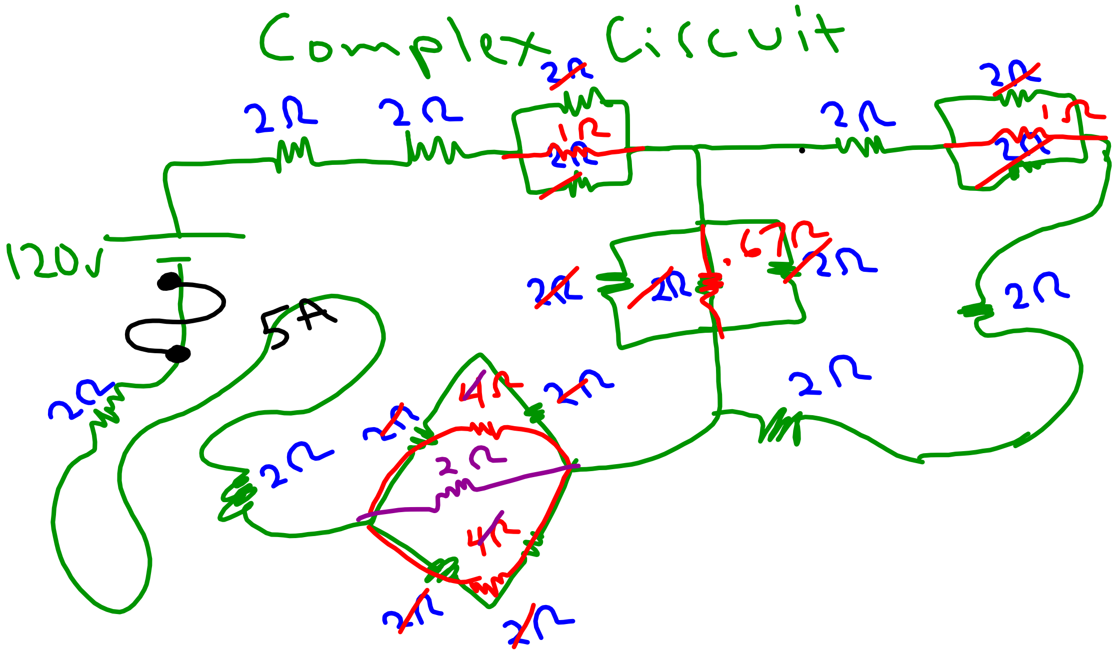


$10 + 12 = R$

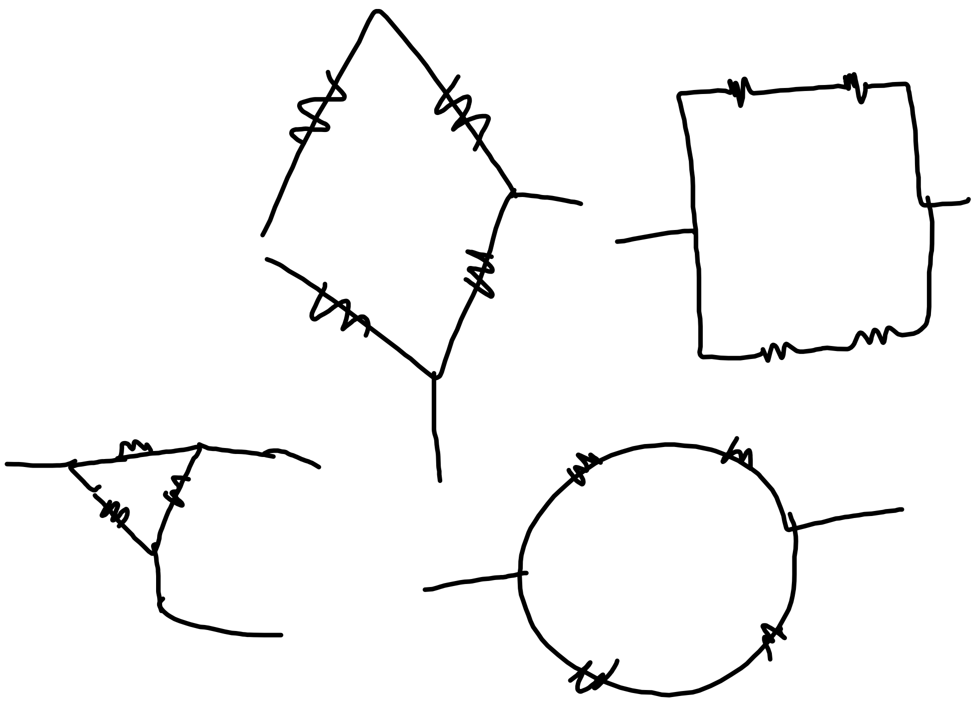
$V = IR$

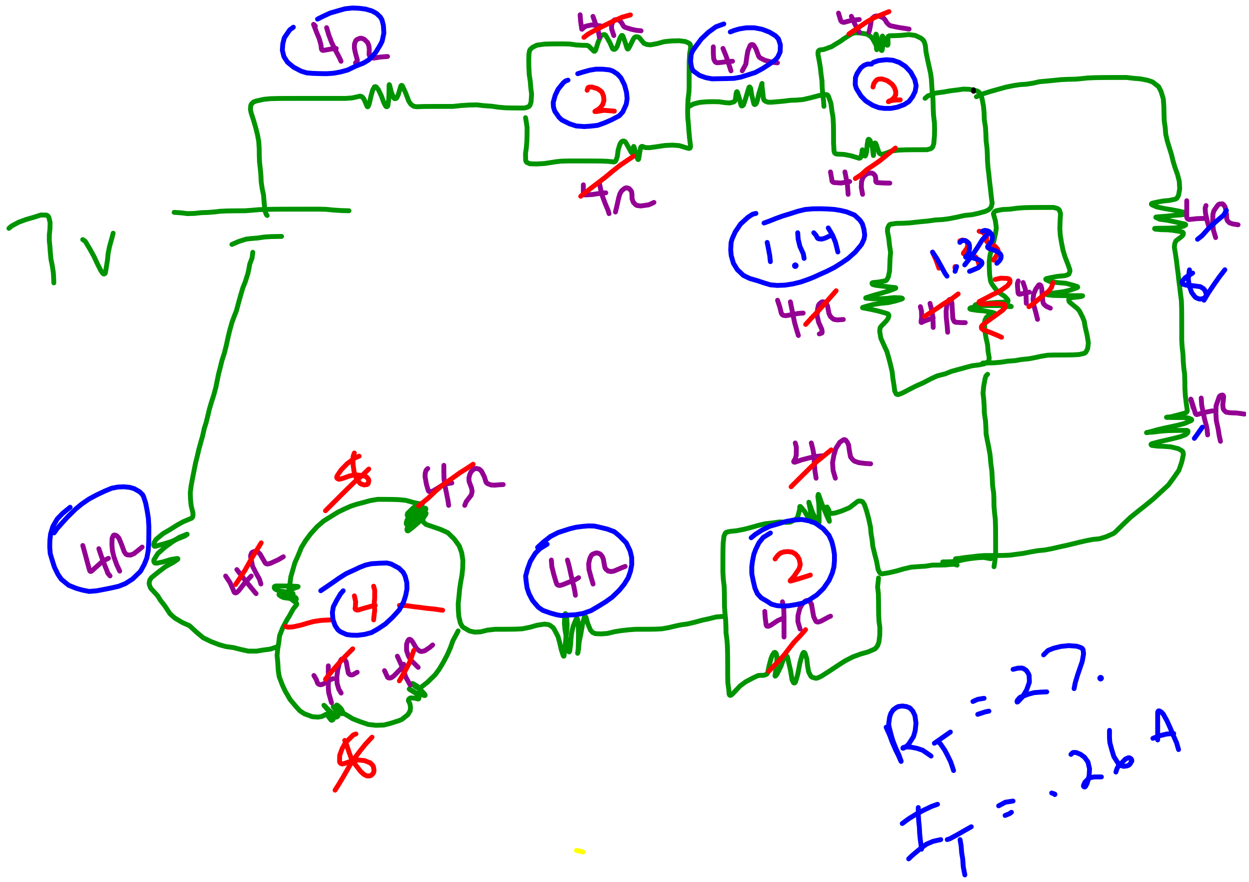
$6 = I(22)$

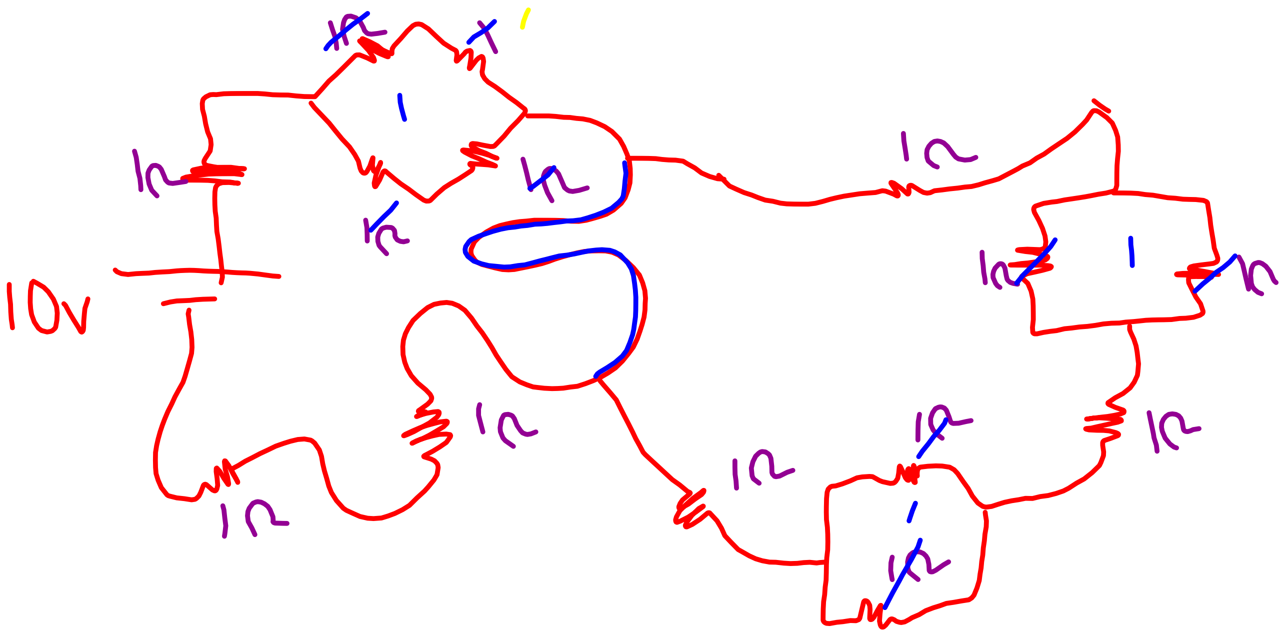
$I_T = .27A$



Find I_t and does the fuse blow?




7 V
4Ω
2
4Ω
2
1.14
4Ω
2
4Ω
4
R_T = 27.
I_T = .26 A

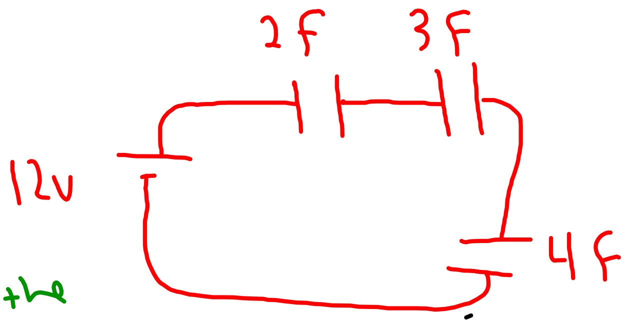

10v
1Ω
1Ω
1Ω
1Ω
1Ω
1Ω
1Ω
1Ω

Capacitors in Circuits

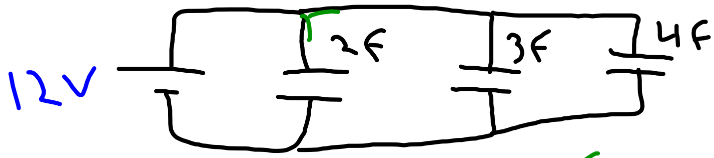
$$\frac{1}{C_T} = \frac{1}{C_1} + \frac{1}{C_2} \ldots$$

Series

$$C = \frac{q}{V}$$



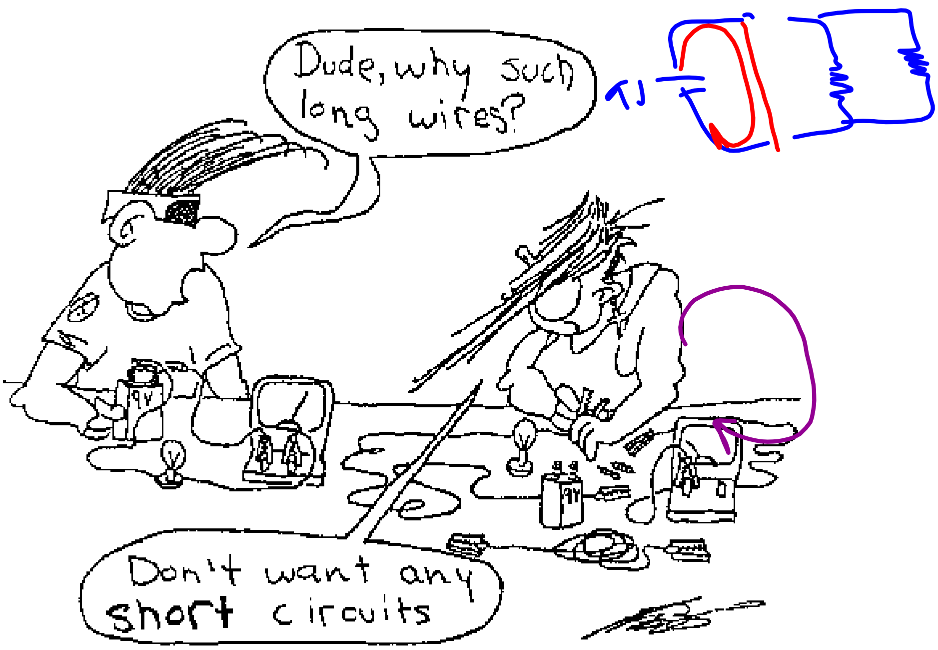
Charge is the same in each capacitor



Parallel

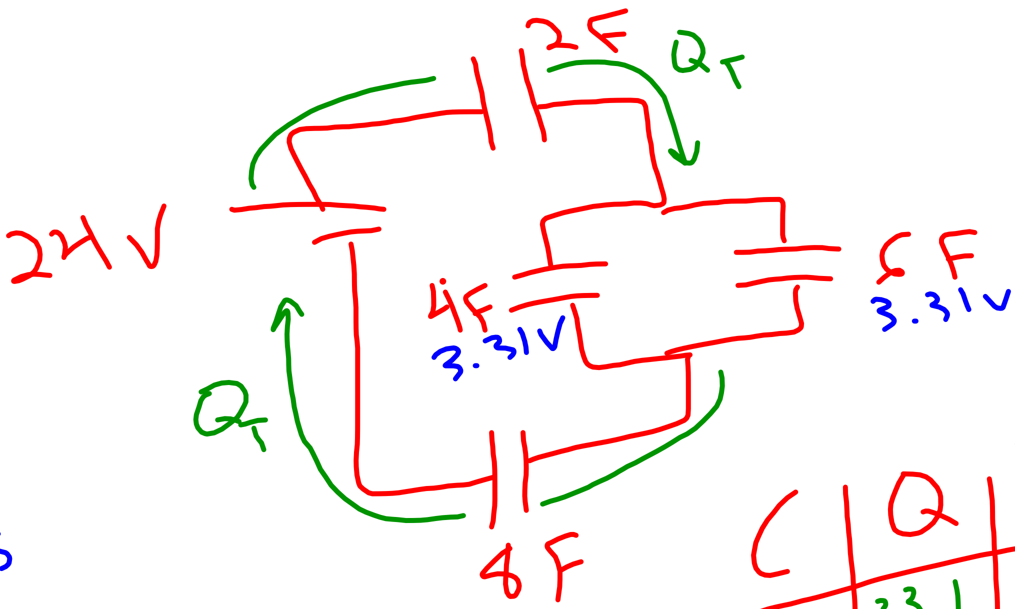
$$C_T = C_1 + C_2 \ldots = F$$

Voltage stays the same across each capacitor



Cartoon by Ehren Stillman, a high-school student from Deroche, BC, Canada.

JAN. 1993 THE PHYSICS TEACHER 57

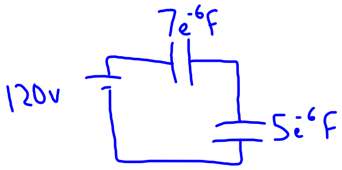


24
- 16.55
- 4.14

3.31V

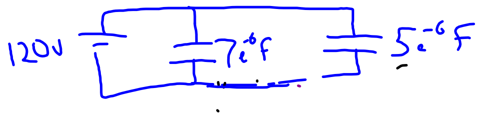
C	Q	V
2	33.1	16.55
4	13.24	3.31
6	19.86	3.31
8	33.1	4.14

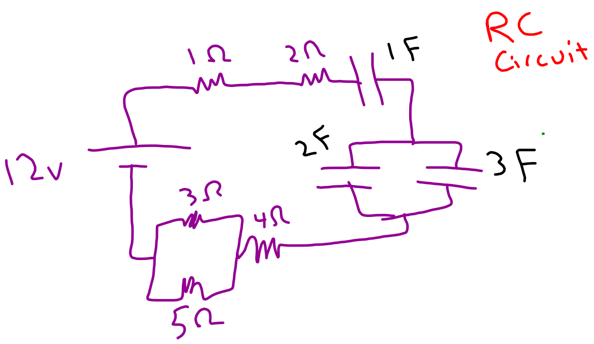
Using Capacitors in circuits

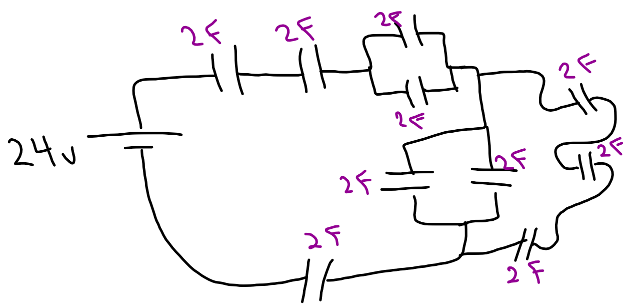


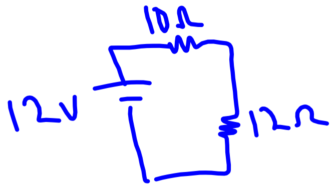
Series
q is constant

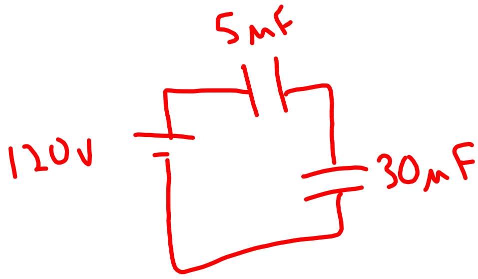
Parallel → Voltage is constant



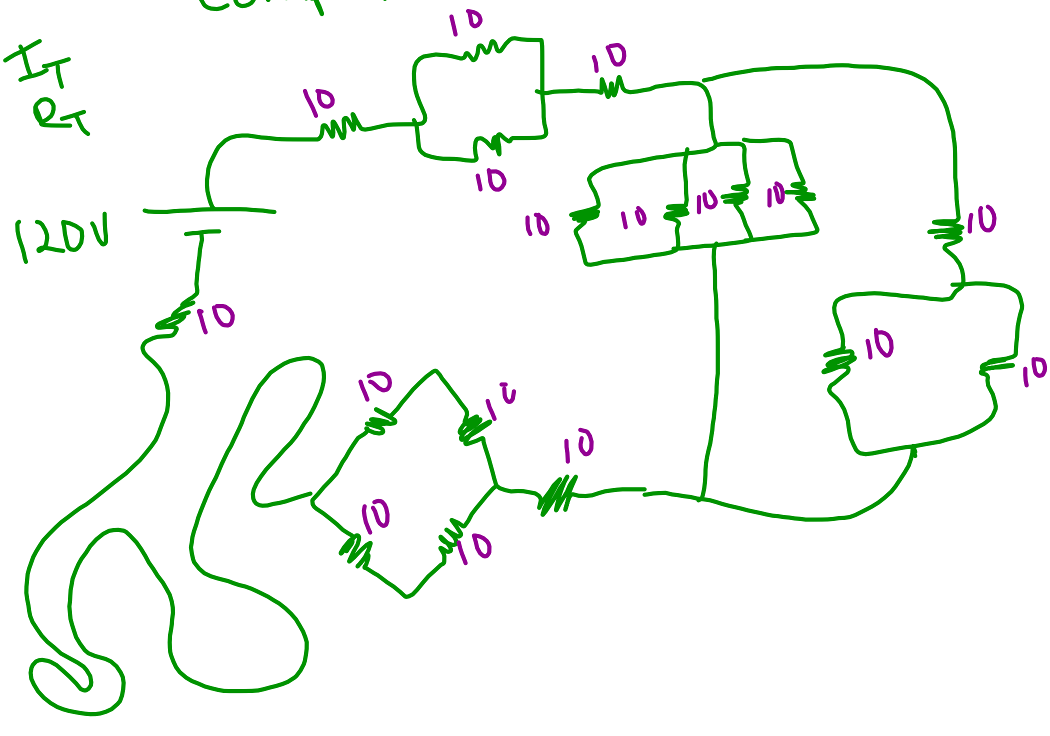


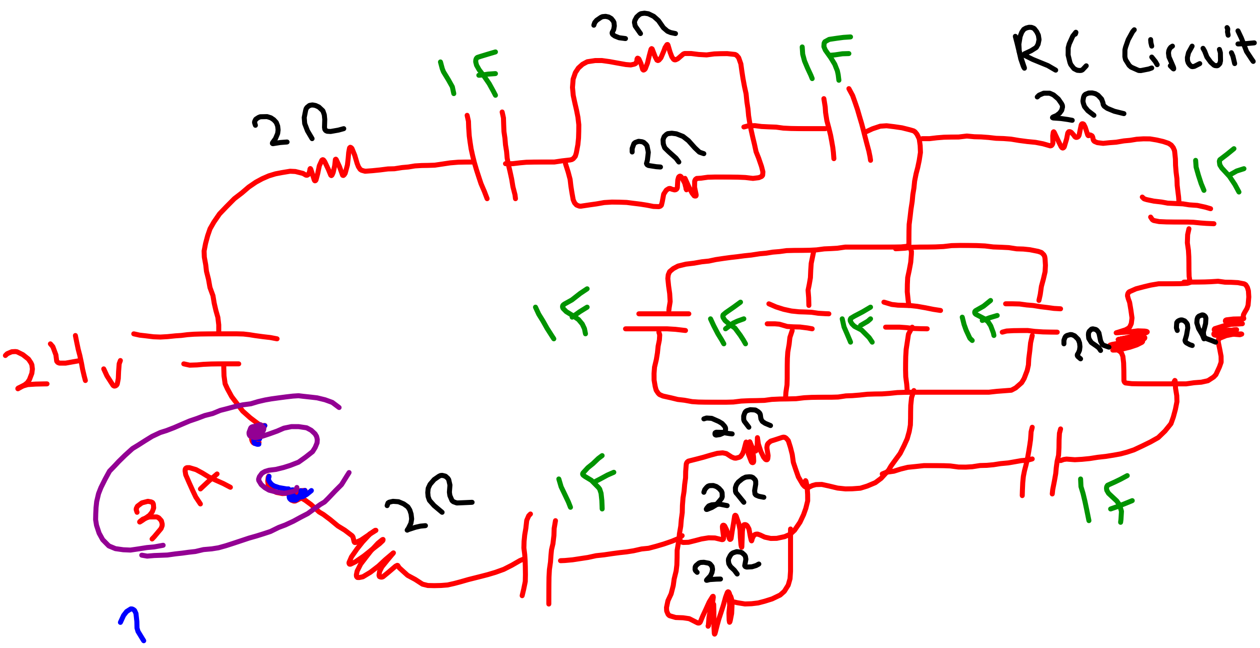






Complex — all —w— 10Ω




RC Circuit
2Ω
1F
2Ω
2Ω
1F
2Ω
1F
24v
3A
1F
1F
1F
1F
2Ω
2Ω
2Ω
2Ω
2Ω
2Ω
1F
1F

$R_T = ?$

$I_T = ?$

$C_T = ?$

$Q_T = ?$

$I_F = \frac{q_2}{q_1}$ $C_0 = \frac{q_0}{V_0}$ q_0 = initial

RC Circuits- when circuits contain both resistors and capacitors

t → amount of time passed

→ Time constant

Charging Capacitor $q = q_o(1 - e^{-t/(RC)})$

$\tau = RC$

charge after time passed, initial

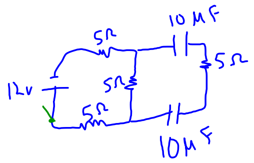
Discharging Capacitor $q = q_o e^{-t/(RC)}$

$\frac{q}{q_0} = e^{-T/RC}$

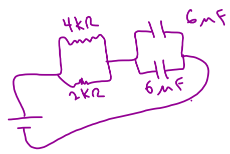
$\tau = RC$ τ → time constant

Tau is the time constant, measured in seconds because an Ohm x Farad = second. The time constant is the amount of time required for the capacitor to accumulate 63.2% of its equilibrium charge. If Tau is small it approaches its charge quickly, if Tau is large if takes a longer time to charge.

Charging
T = ?
30%
τ = RC

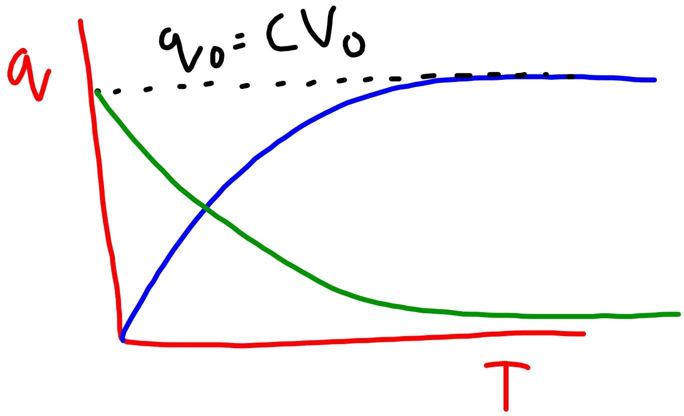


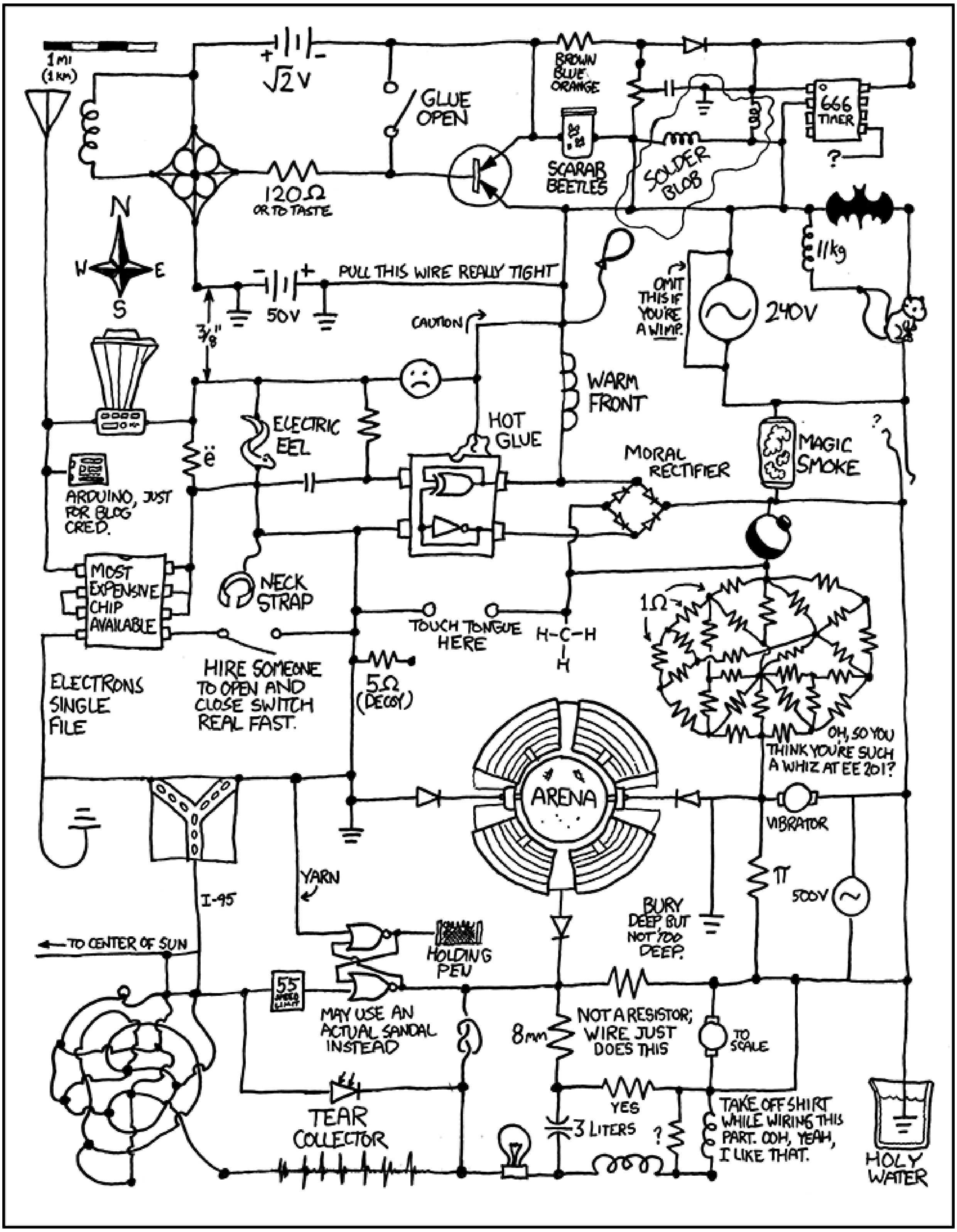
75% charged
T = ?
discharge



Ch20: 2,5,7,9,12,13,17,20,21,24,26,28,41,
44,47,50,54,58,61,63,70,73,77,78,
82,86,88,92,96

Green Book
Ch 22 MC: 22, 24, 27


q
$q_0 = CV_0$
T


1 MI
(1 KM)
√2 V
GLUE OPEN
BROWN
BLUE
ORANGE
666 TIMER
?
SCARAB BEETLES
SOLDER BLOB
120Ω
OR TO TASTE
N
W
E
S
PULL THIS WIRE REALLY TIGHT
50V
3/8"
CAUTION
OMIT THIS IF YOU'RE A WIMP
240V
WARM FRONT
ELECTRIC EEL
HOT GLUE
ë
ARDUINO, JUST FOR BLOG CRED.
MORAL RECTIFIER
MAGIC SMOKE
?
MOST EXPENSIVE CHIP AVAILABLE
NECK STRAP
1Ω
TOUCH TONGUE HERE
H-C-H
H
ELECTRONS SINGLE FILE
HIRE SOMEONE TO OPEN AND CLOSE SWITCH REAL FAST.
5Ω (DECOY)
OH, SO YOU THINK YOU'RE SUCH A WHIZ AT EE 201?
ARENA
VIBRATOR
π
500V
YARN
I-95
BURY DEEP BUT NOT TOO DEEP.
TO CENTER OF SUN
HOLDING PEN
55
MAY USE AN ACTUAL SANDAL INSTEAD
NOT A RESISTOR; WIRE JUST DOES THIS
8mm
TO SCALE
TEAR COLLECTOR
YES
3 LITERS
?
TAKE OFF SHIRT WHILE WIRING THIS PART. OOH, YEAH, I LIKE THAT.
HOLY WATER

Internal Resistance- the internal resistance of a battery will reduced the amount of voltage running through the circuit. The amount of current will also effect the voltage drop across the battery. perfect world

inside battery
$V = IR$

$V_T = \mathcal{E}mf - V_i$
leaves battery

emf = 12V

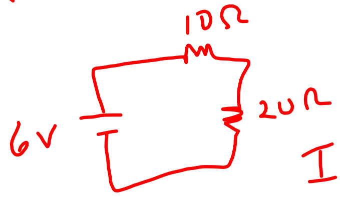
$R_i = .01\Omega$

$I = 10A$, 100A

$V_T = ?$

ρ - resistivity

$$R = \frac{\rho L}{A}$$



$I_T = .2A$

$R_i = .01\Omega$

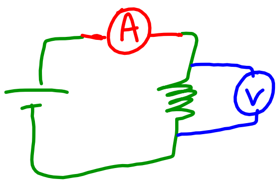
$V_i = .002V$

$V_T = 6 - .002$

Ammeter → I → series

Voltmeter → V → parallel

Ohmmeter → R → parallel with an open circuit



Ohmic → resistance is constant regardless of current

Non ohmic → resistance changes based on current

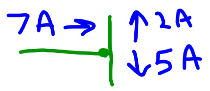
ex. semiconductor diode

pg 724

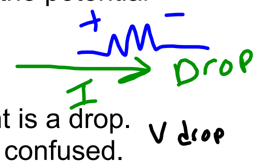
Kirchoffs Law

Read pg 741

Rule 1: The sum of magnitudes of the currents directed into a junction equals the sum of the magnitude of the currents directed out of a junction



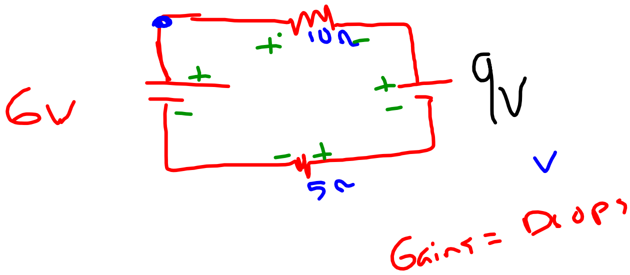
Rule 2: Around any closed-circuit loop, the sum of the potential drops equals the sum of the potential rises.

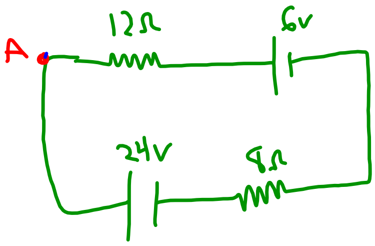


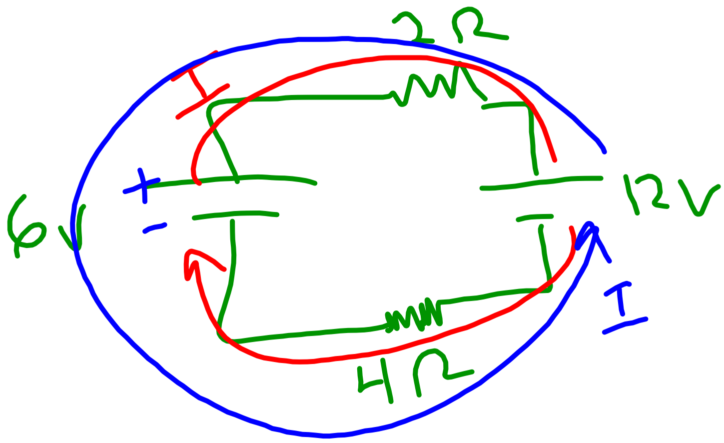
going across a battery from - to + is a potential rise
going across a resistor in the direction of the current is a drop.
Label each resistor with a plus and minus to not be confused.

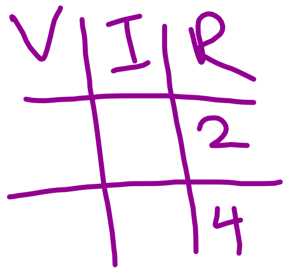
Set up a system of equations based off of each loop.

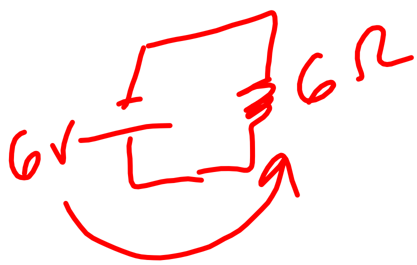
Voltage drops = Voltage Gains

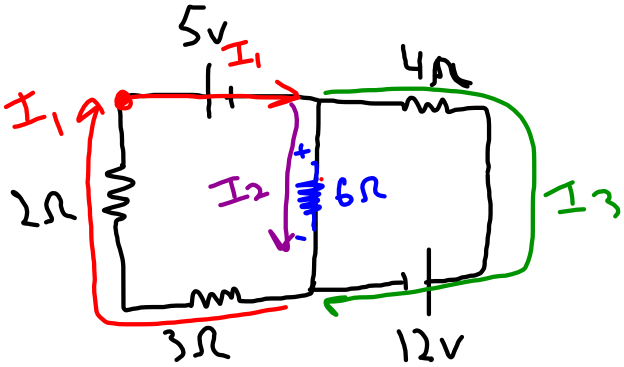





2 Ω
6 V
12 V
4 Ω
I
I
+
-


V
I
R
2
4


6 V
6 Ω
+



V I R P

$(-5 = 11I_2 + 5I_3)\,9$

$(-17 = 5I_2 + 9I_3)\,-5$

$-45 = 99I_2 + 45I_3$

$+\ 85 = -25I_2 - 45I_3$

$40 = 74I_2$

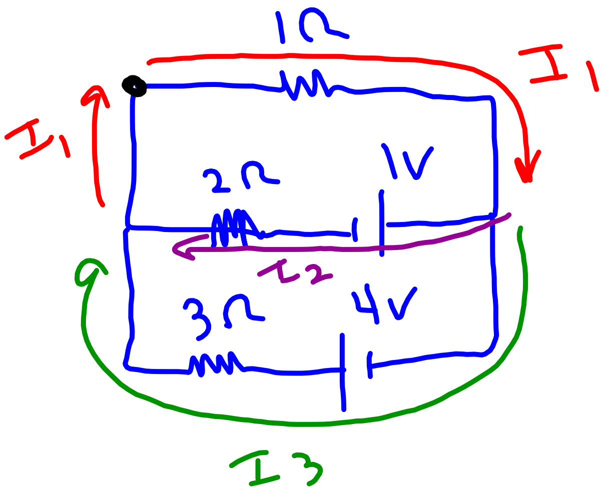
$I_2 = .541\text{A}$

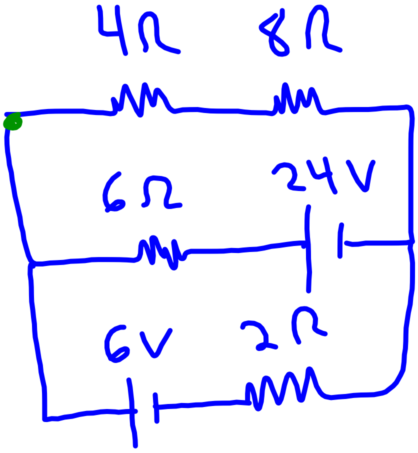
$-5 = 6(.541) + 5I_1$

$I_1 = -1.65\text{A}$

$-1.65 = .541 + I_3$

$I_3 = -2.19\text{A}$


1Ω
I1
I1
2Ω
1V
I2
3Ω
4V
I3



$I_1 = .78\text{ A}$

$I_2 = 2.45\text{ A}$

$I_3 = -1.66\text{ A}$

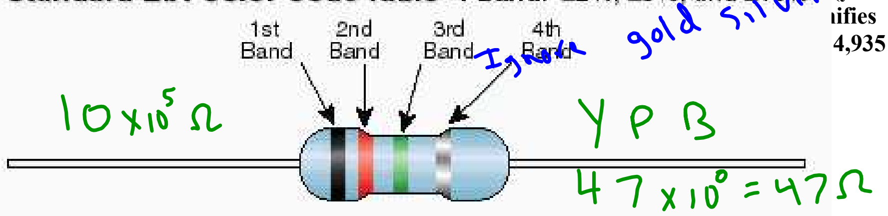
$6 = 2I_3 + 12I_1$

It is sometimes not obvious whether a color coded component is a resistor, capacitor, or inductor, and this may be deduced by knowledge of its circuit function, physical shape or by measurement.

A diagram of a resistor, with four color bands A, B, C, D from left to right A diagram of a 2.7 MΩ color-coded resistor.
To distinguish left from right there is a gap between the C and D bands.

* band A is first significant figure of component value (left side)
* band B is the second significant figure
* band C is the decimal multiplier
* band D if present, indicates tolerance of value in percent (no color means 20%)

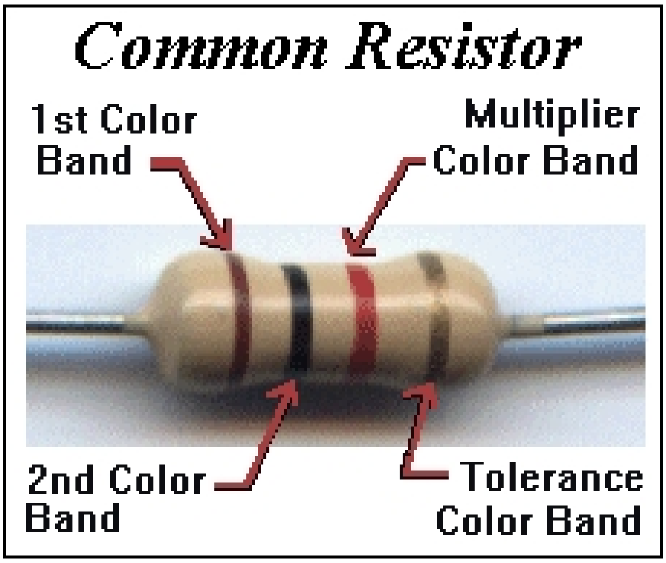
Standard EIA Color Code Table 4 Band: ±2%, ±5%, and ±10% (yellow
ifies
4,935



Color	1st Band (1st figure)	2nd Band (2nd figure)	3rd Band (multiplier)	4th Band (tolerance)
Black	0	0	10^0	
Brown	1	1	10^1	
Red	2	2	10^2	±2%
Orange	3	3	10^3	
Yellow	4	4	10^4	
Green	5	5	10^5	
Blue	6	6	10^6	
Violet	7	7	10^7	
Gray	8	8	10^8	
White	9	9	10^9	
Gold			10^{-1}	±5%
Silver			10^{-2}	±10%

02×10^5

A resistor which (read left to right) displays the colors yellow, violet, yellow, brown. The first two bands represent the digits '4, 7. The third band, another yellow, gives the multiplier 10^4. The value is then $47 \times 10^4\ \Omega$, or 470 kΩ. The brown band is a s then a tolerance of ±1%.



A Ohmmeter measures resistance

attached to the object when circuit is off.

A Voltmeter measures voltage

attached in parallel to the resistor when circuit is on

An Ammeter measures current

attached in series before the resistor when circuit is on

Attachments

- edison
- electric man
- doorknob current
- xkcd Circuit Diagram.mht