

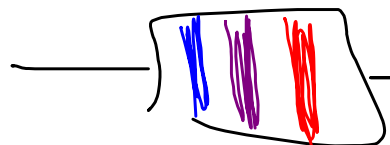
DRAFT

NOTES

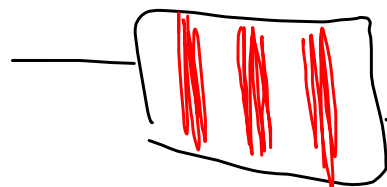
RESISTOR

COLOUR

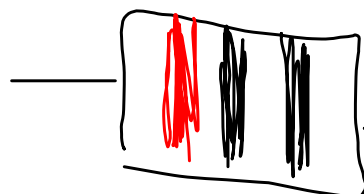
CODES.



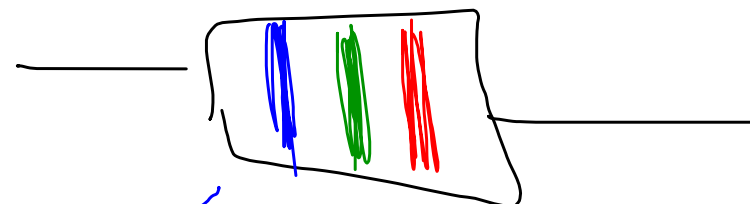
6.7k



2.2k



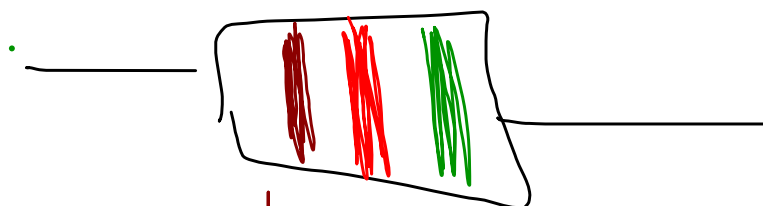
20Ω



6 5 0 0

6.5kΩ

6k5Ω

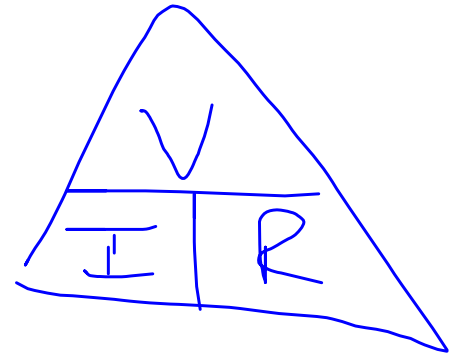
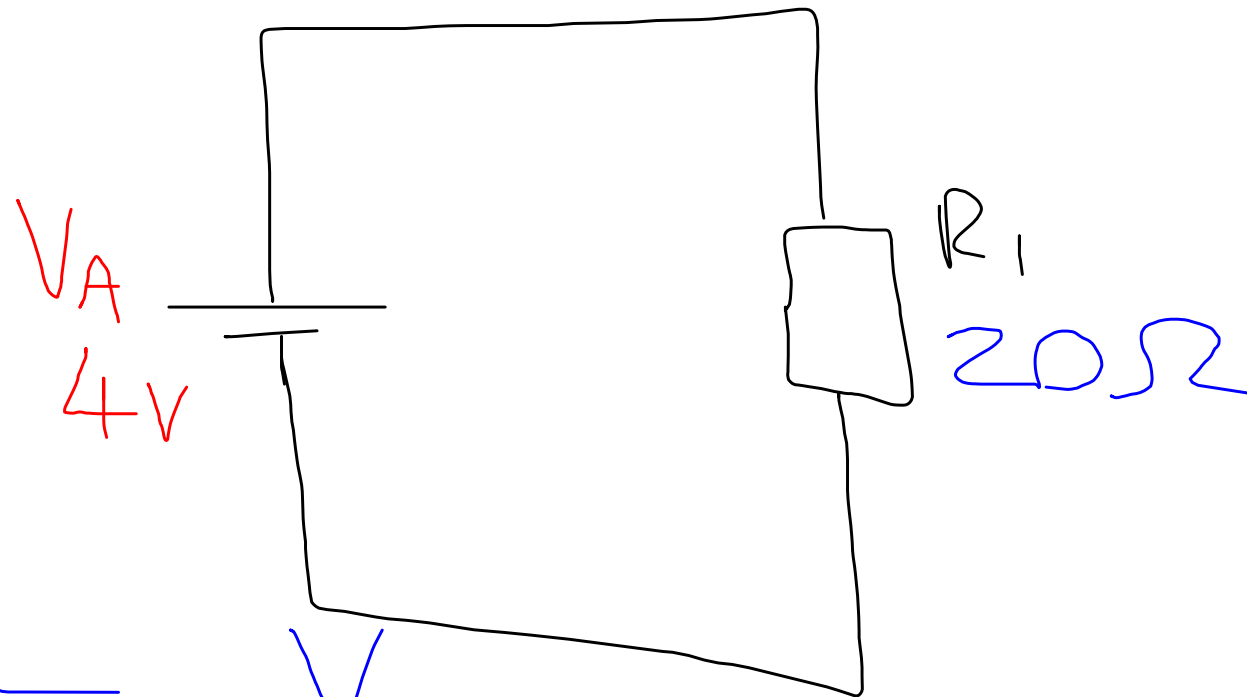


1 2 0 0 0 0 0

1.2MΩ

1M2Ω

HOW MUCH CURRENT WILL FLOW?

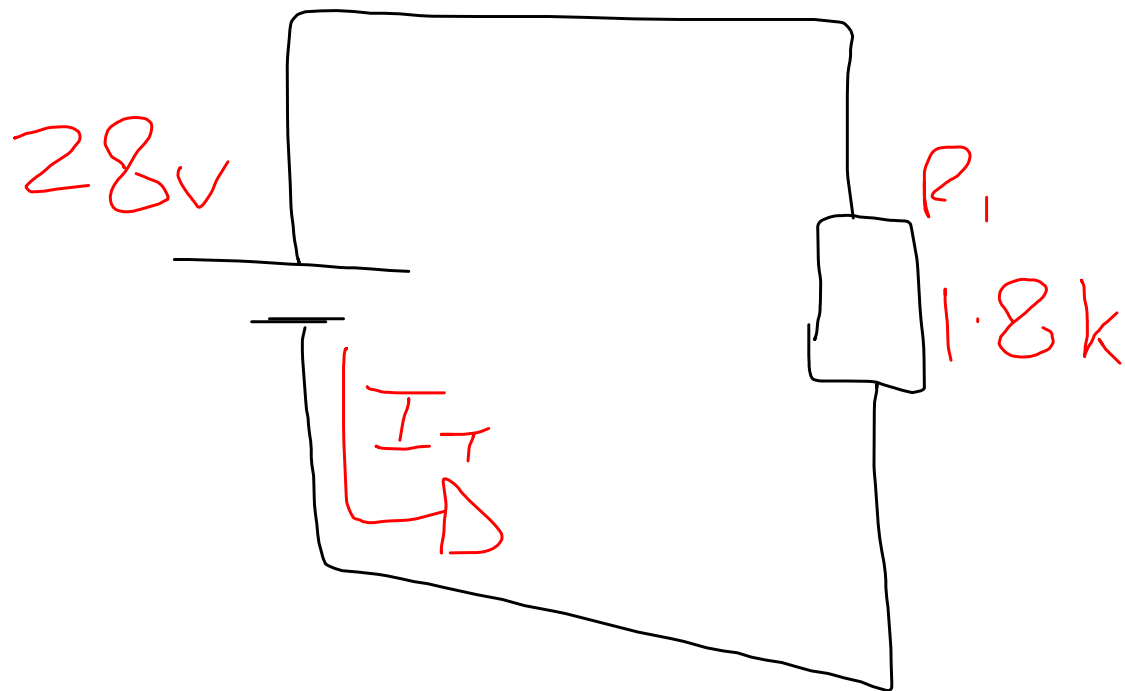


$$I = \frac{V}{R}$$

$$I = \frac{4V}{20\Omega}$$

$$= 0.2A = 200mA$$

CURRENT IN
SERIES.

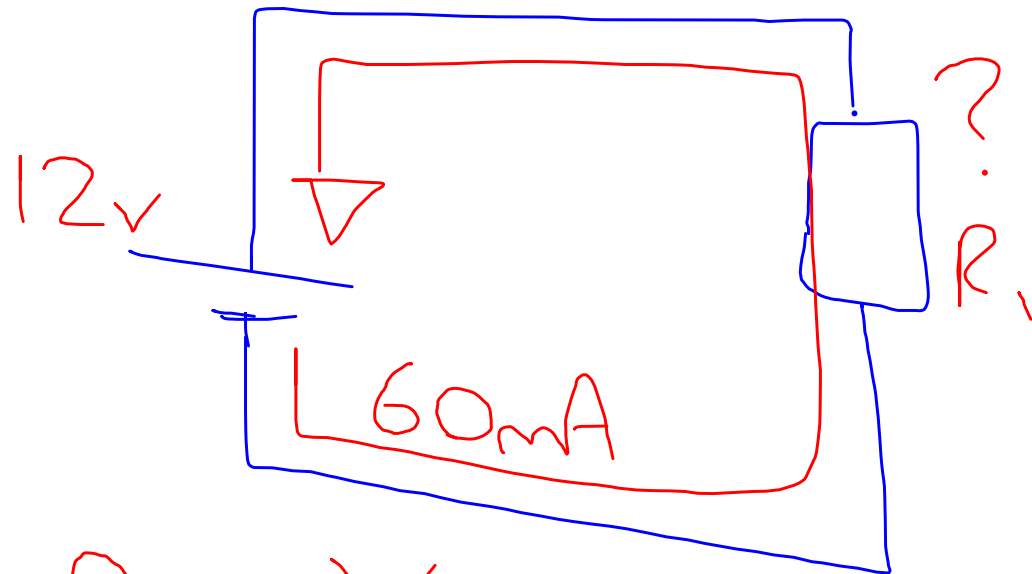


$$I_T = \frac{V}{R}$$

$$= \frac{28v}{1.8k}$$

$$= 15.56mA$$

WE WANT 60mA OF CURRENT



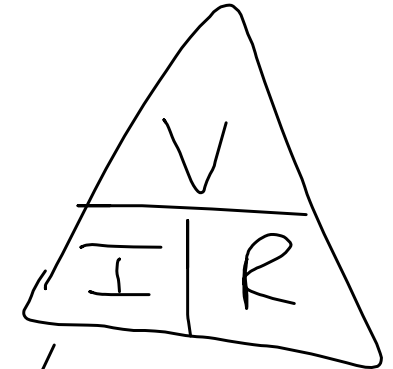
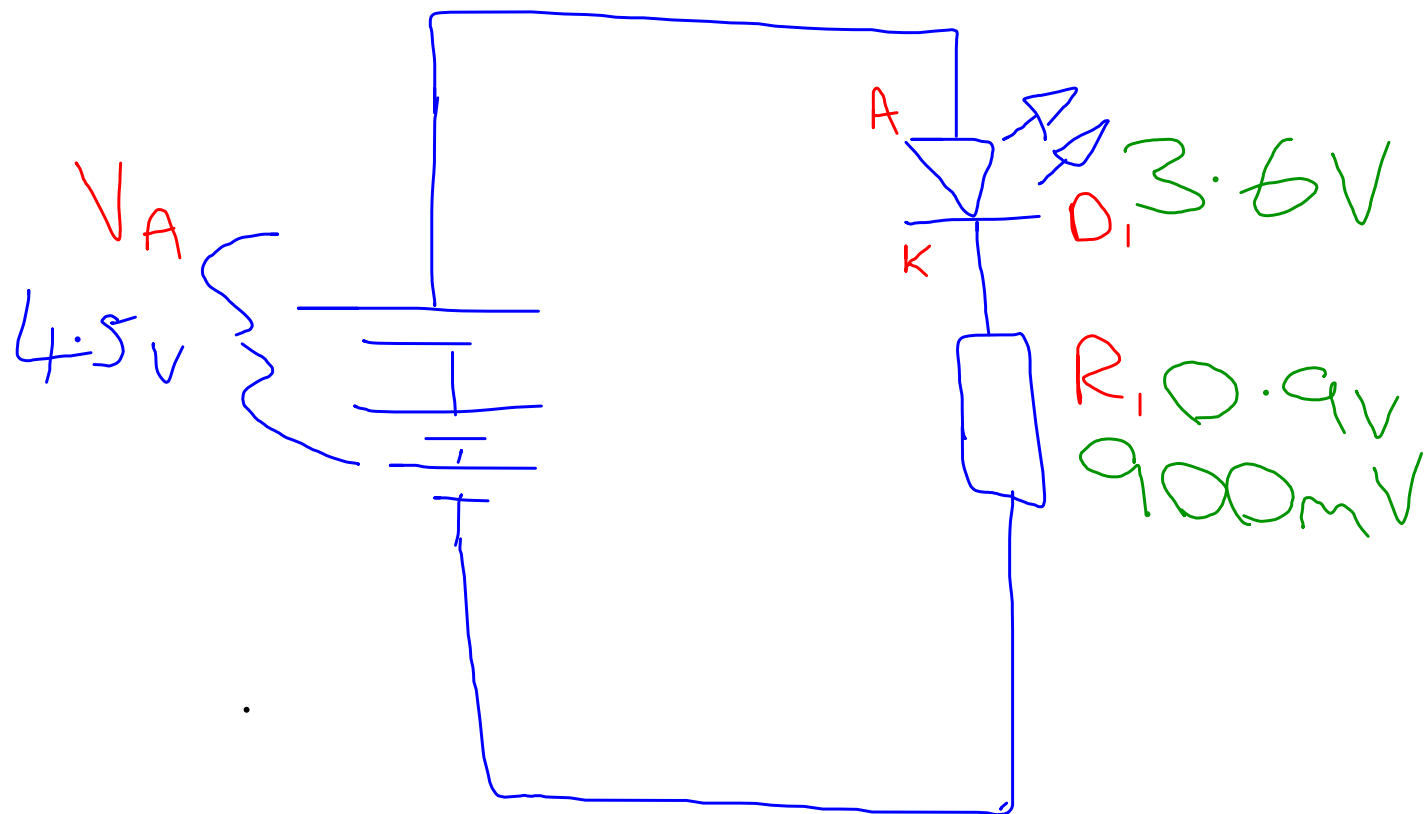
$$R = \frac{V}{I}$$

$$R = \frac{12V}{60mA}$$

$$R = 200\Omega$$

RESISTORS CAN BE USED TO LIMIT CURRENT

(WANT TO LIMIT CURRENT
TO 20mA)

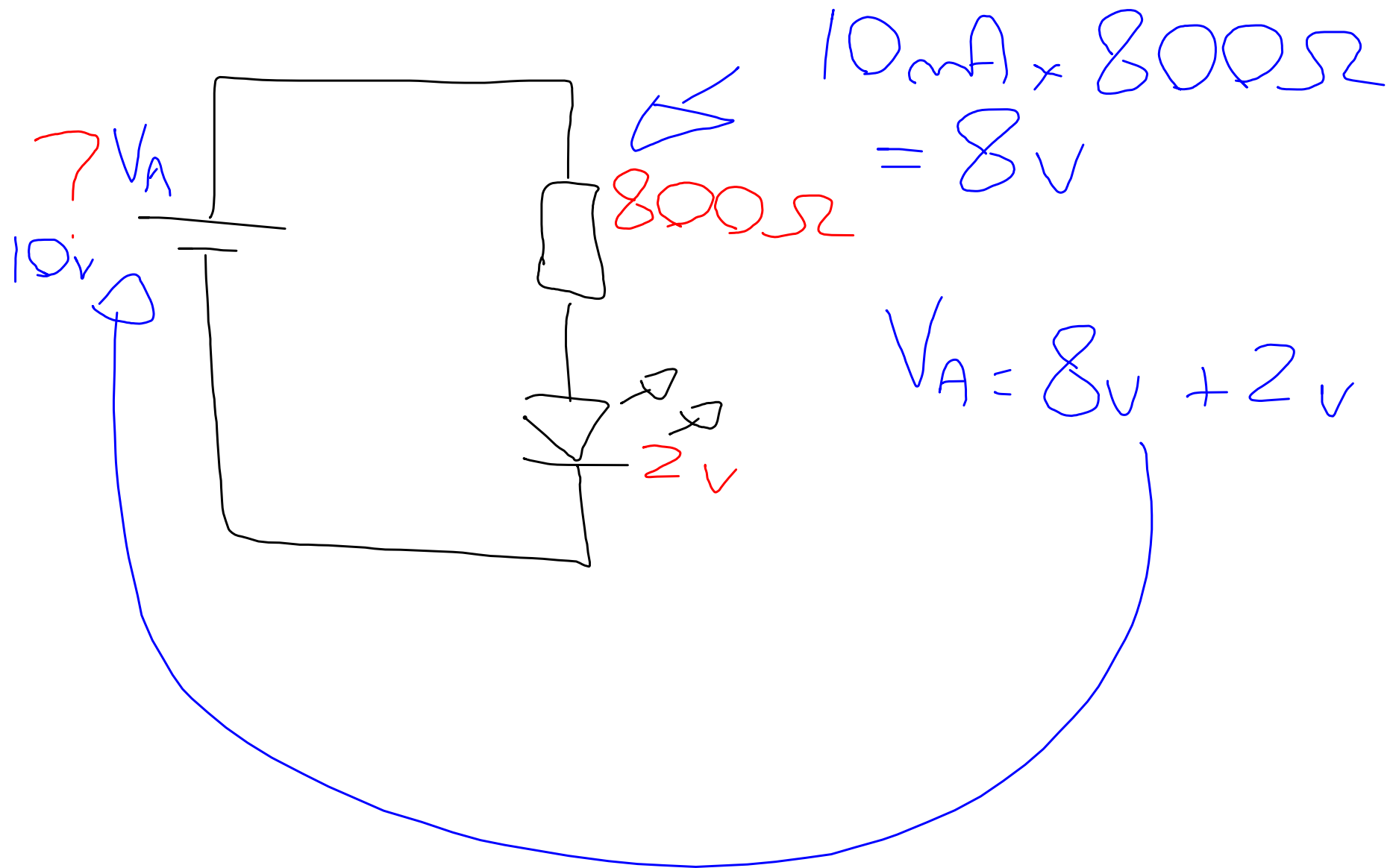


$$R = \frac{V}{I}$$

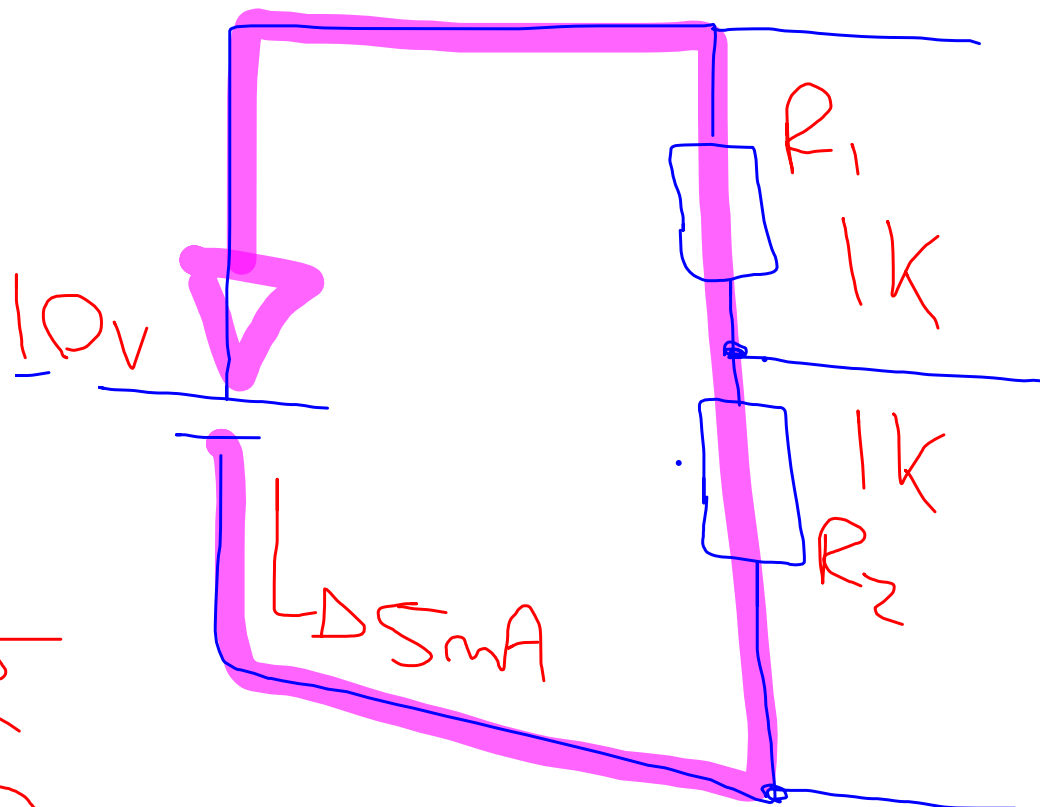
$$R = \frac{900\text{mV}}{20\text{mA}}$$

$$R = 45\Omega$$

WHAT VOLTAGE TO GET 10mA OF CURRENT



RESISTORS CAN BE USED TO
DIVIDE UP VOLTAGE.



^{IN SERIES}
 $R_T = R_1 + R_2$

$$R_T = 1k + 1k$$

$$R_T = 2k$$

$$V_{R_2} = I_{R_2} \times R_2$$

$$V_{R_2} = 5mA \times 1k$$

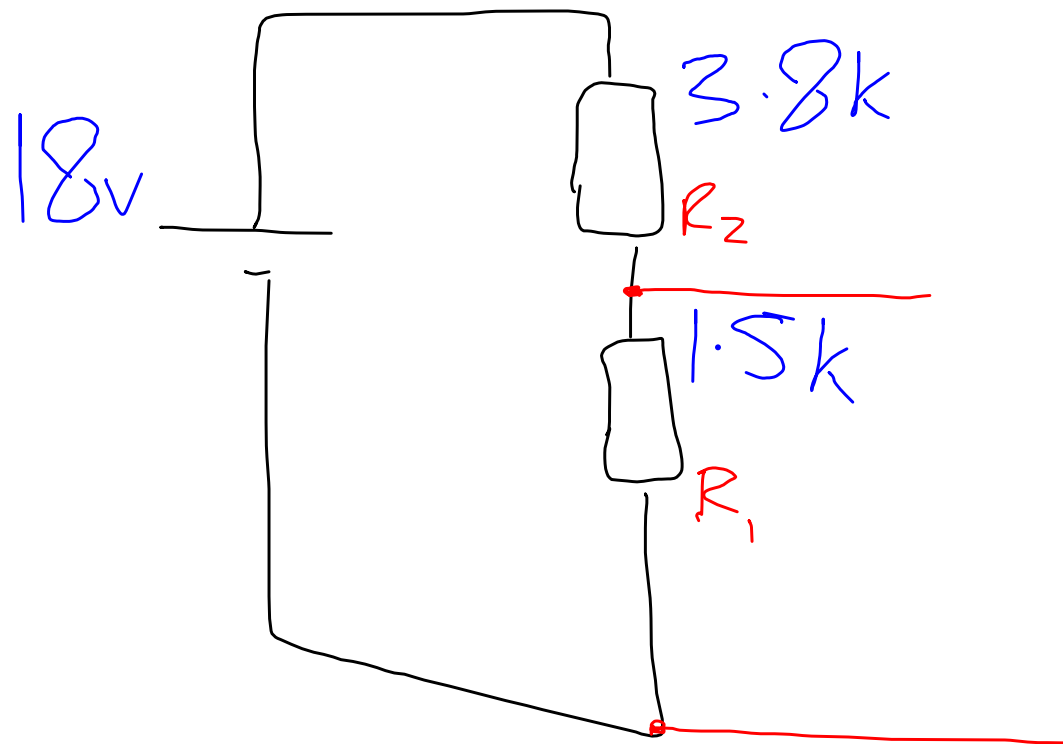
$$V_{R_2} = 5V$$

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

$$I = \frac{10V}{2k}$$

$$I = 5mA$$

$$\begin{aligned} V_{R_1} &= I_{R_1} \times R_1 \\ &= 5mA \times 1k \\ &= 5V \end{aligned}$$



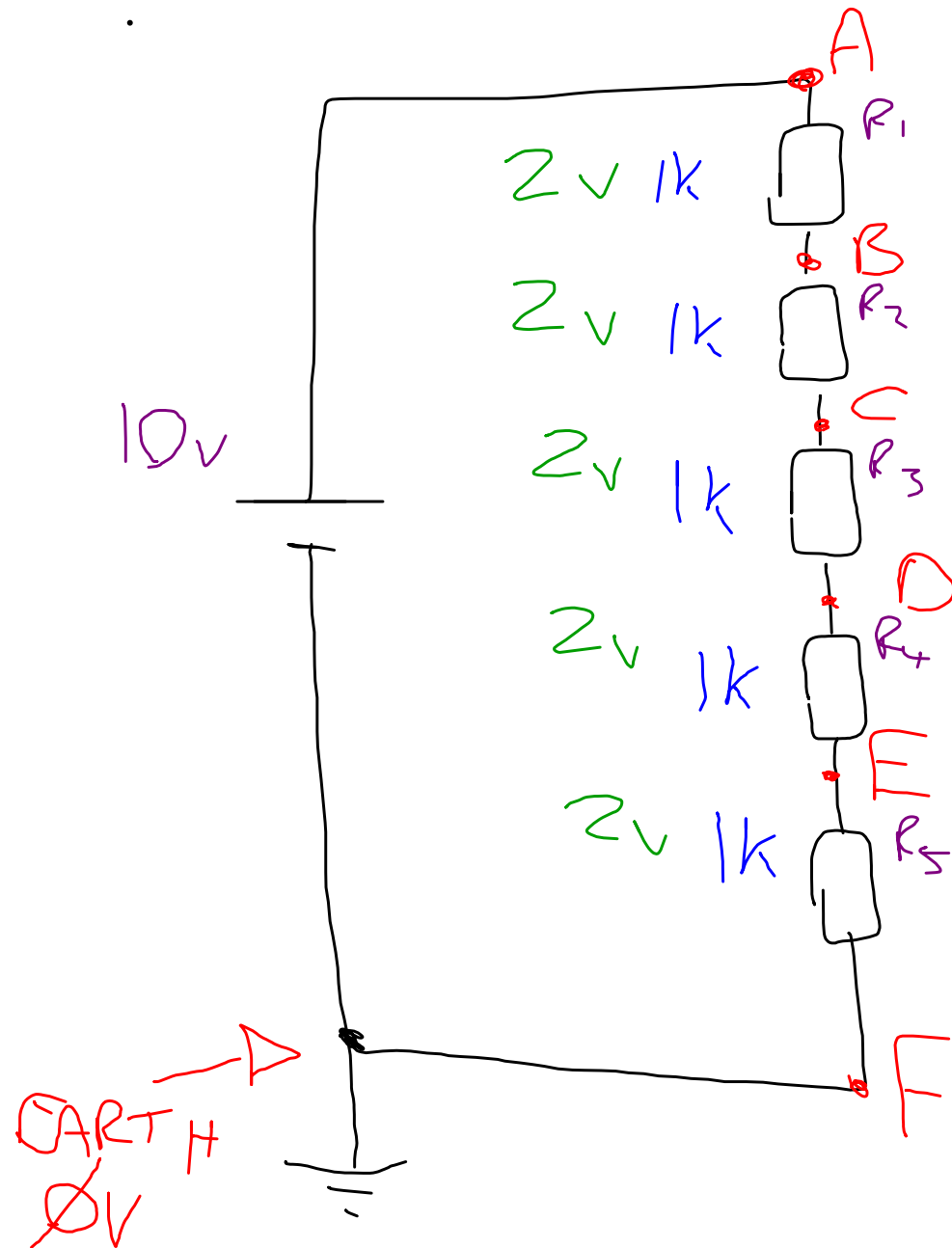
$$\begin{aligned} R_T &= R_1 + R_2 \\ &= 1.5k + 3.8k \\ &= 5.3k \end{aligned}$$

$$\begin{aligned} I_T &= \frac{18v}{5.3k} \\ &= 3.4mA \end{aligned}$$

$$\begin{aligned} V_{R_1} &= 3.4mA \times 1.5k \\ &= 5.1v \end{aligned}$$

$$\begin{aligned} V_{R_2} &= 3.4mA \times 3.8k \\ &= 12.92v \end{aligned}$$

Voltages with respect to different points.



$$V_{AF} = 10V$$

$$V_{AB} = 2V$$

$$V_C = 6V$$

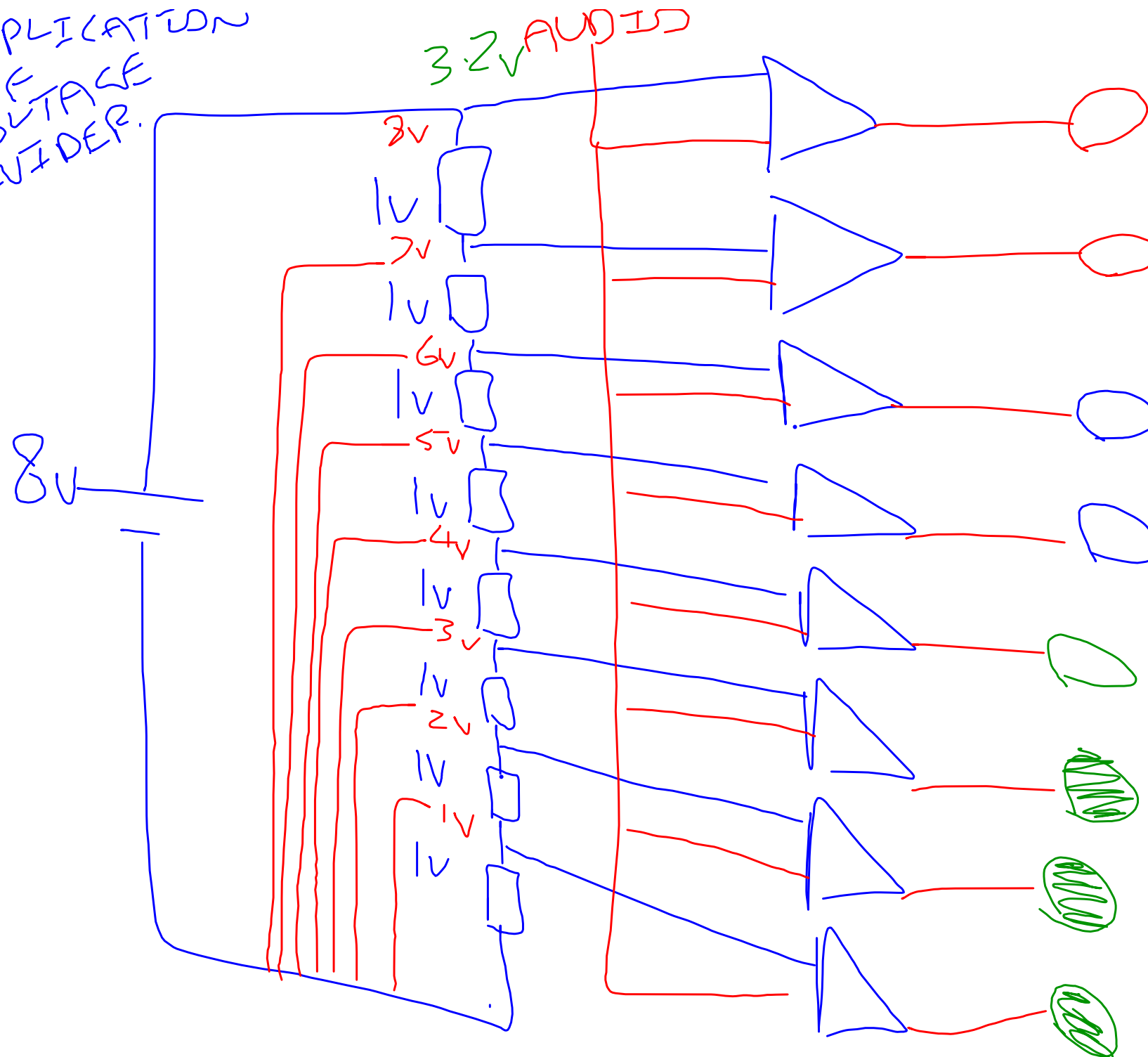
$$V_{CD} = 2V$$

$$V_{EB} = -6V$$

The first letter after the V is where you place your RED multimeter lead. The second letter (if any) is where you place your black lead. If there is no second letter, then your black leads goes to ground (aka earth).

When we say 'what is V_{af} ' we are actually saying 'what is the voltage at 'a' compared to the voltage at 'f'. In other words what is the difference in potential between 'a' and 'f'.

APPLICATION OF VOLTAGE DIVIDER.

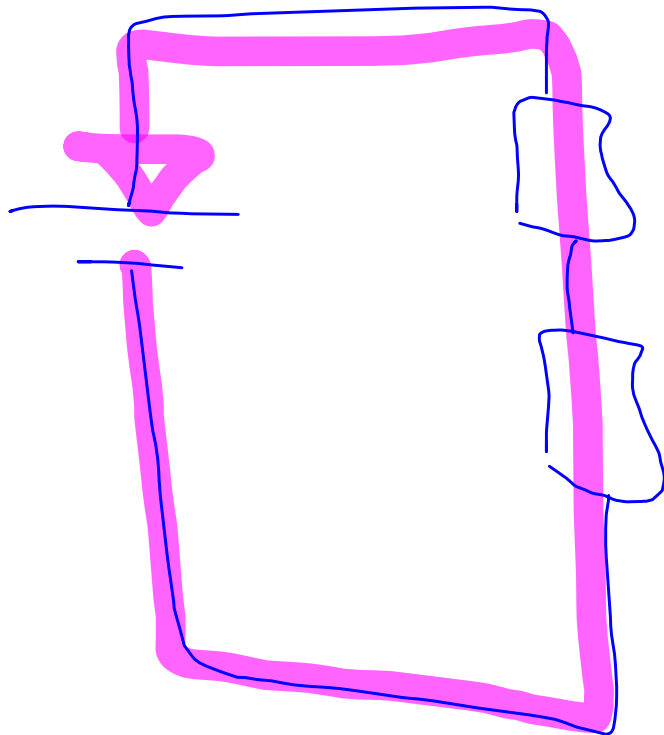


LED audio level meter. This circuit uses a voltage divider to give us all sorts of reference voltages for which we can then compare an incoming audio signal. The audio level is compared to 1v, 2v, 3v, 4v, 5v, 6v, 7v and 8v. If the incoming audio is greater than any of these voltages, it will cause the corresponding LED to come on.

E.G. if the audio at one point in time was 3.2V then it would light up three LED's because 3.2V is greater than 1v, 2v and 3v but it is less than 4v, 5v, 6v, 7v and 8v. etc...

3 TYPES OF RESISTIVE CIRCUITS.

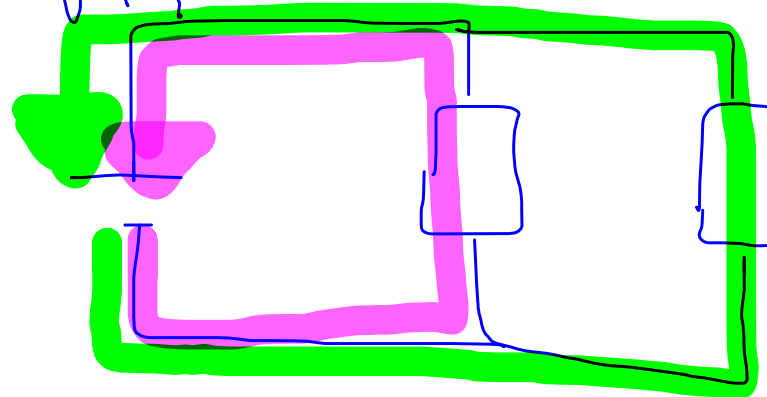
SERIES



current in a series circuit is the same throughout, This is because there are no alternative paths for the current to follow. This will result in a certain voltage drop across each resistor in the circuit.

I.E. In a series circuit current is the same, but voltage splits up.

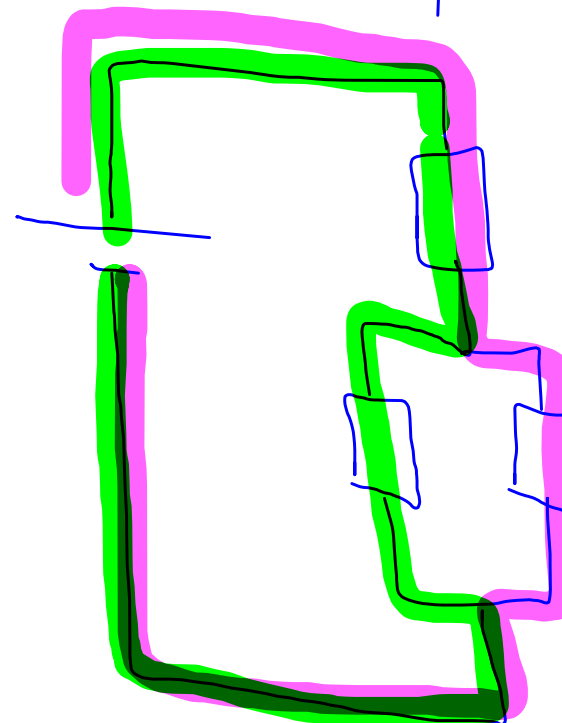
PARALLEL



current in a parallel circuit can split up because there is now more than one path to follow. The voltage however is the same across each component (that's because the tops of the components are shorted to each other and the bottoms of each component are shorted to each other).

I.E. In a parallel circuit voltage is the same and current splits up.

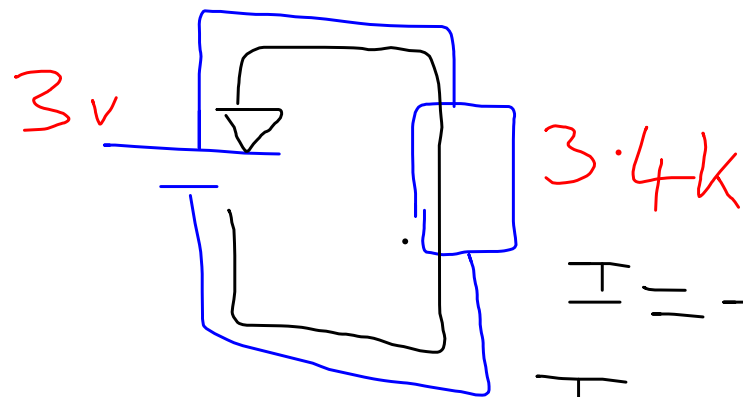
SERIES/PARALLEL



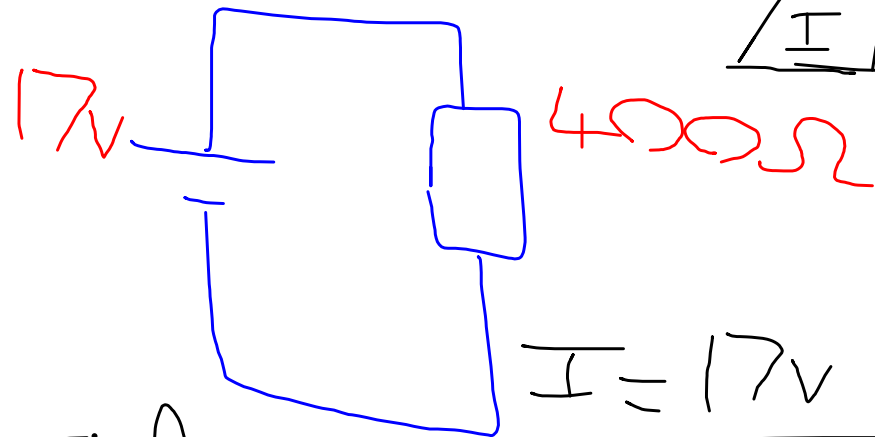
Series / parallel is simply a circuit with both series resistors and parallel resistors. in this case, we have the two bottom resistors in parallel with one another so current will split up between them.

We then have the top resistor in series with the bottom two, I.E. the current from the bottom two will combine together and both of these currents will go through the top resistor.

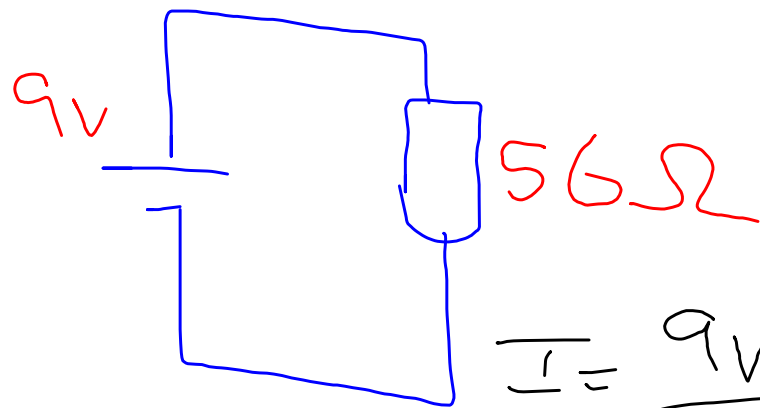
FIND THE CURRENT: (I)



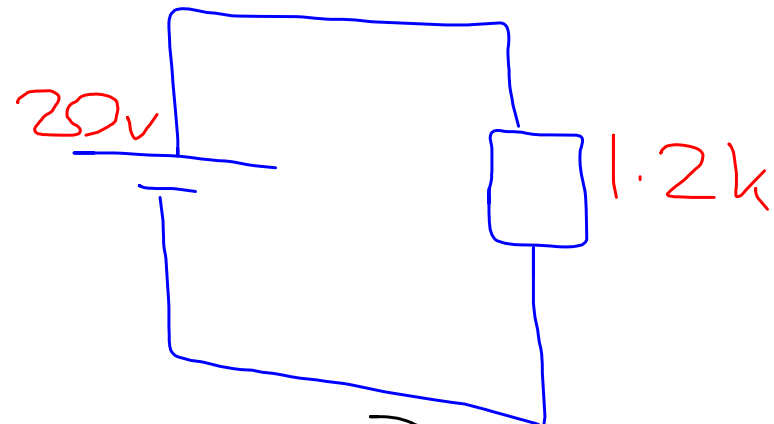
$$I = \frac{3V}{3.4k}$$
$$I = 882.35 \mu A$$



$$I = \frac{17V}{400\Omega}$$
$$I = 42.5 mA$$



$$I = \frac{9V}{56\Omega}$$
$$I = 160.71 mA$$



$$I = \frac{20V}{1.2k}$$
$$I = 16.67 mA$$

FIND THE VOLTAGE DROPS.

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



NEED TO FIND R_T FIRST

$$R_T = R_1 + R_2$$

$$R_T = 1k + 2k$$

$$R_T = 3k$$

①

THEN FIND I_T

$$I_T = \frac{V_A}{R_T}$$

$$I_T = \frac{6V}{3k}$$

$$I_T = 2mA$$

②

THEN FIND V_{R1}

$$V_{R1} = I_{R1} \times R_1$$

$$V_{R1} = 2mA \times 1k$$

$$V_{R1} = 2V$$

③

FINALLY YOU CAN FIND V_{R2}

$$V_{R2} = I_{R2} \times R_2$$

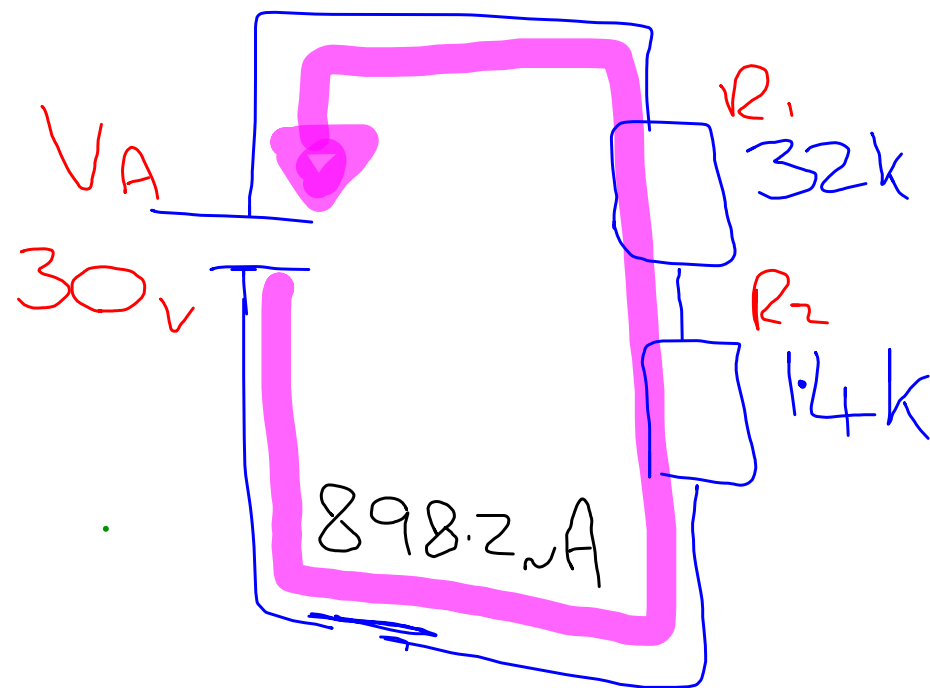
$$V_{R2} = 2mA \times 2k$$

$$V_{R2} = 4V$$

④

$$V_{R1} + V_{R2} = V_A$$
$$2V + 4V = 6V$$

FIND VOLTAGE DROPS:



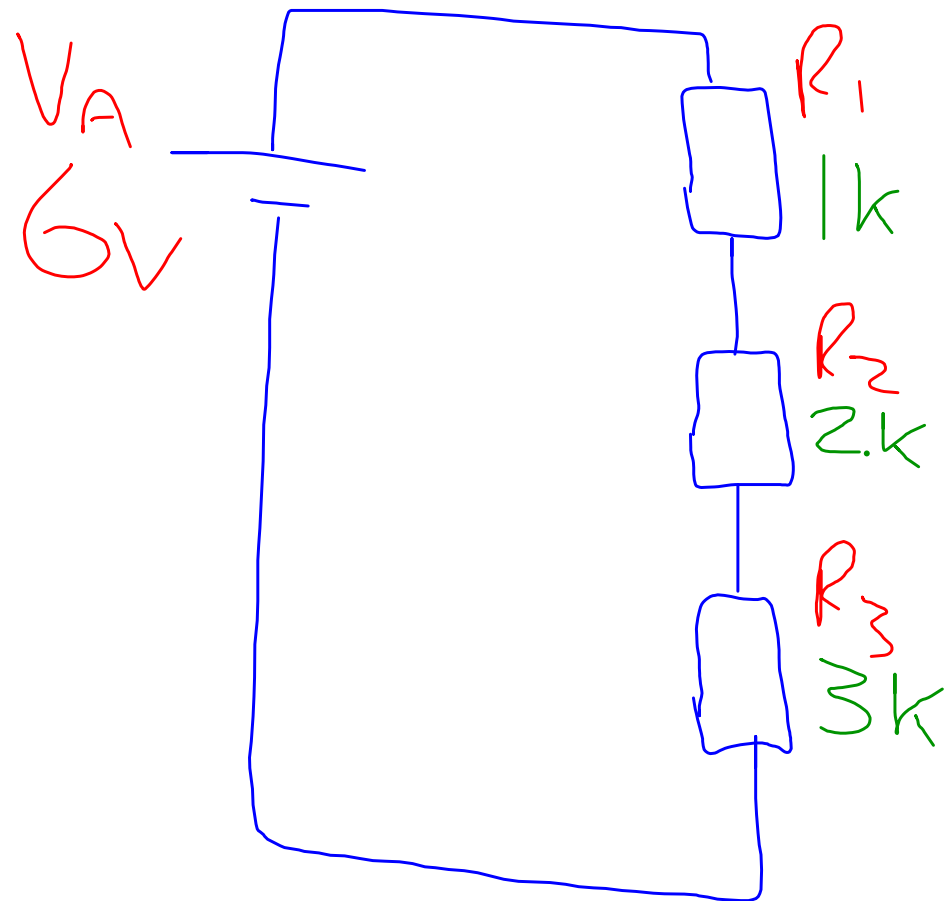
$$R_T = 32k + 1.4k \\ = 33.4k$$

$$I_T = \frac{30V}{33.4k} \\ I_T = 898.2\mu A$$

$$V_{R_1} = 898.2\mu A \times 32k \\ = 28.74V$$

$$V_{R_2} = 898.2\mu A \times 1.4k \\ = 1.26V$$

FIND VOLTAGE DROPS:



FIND VOLTAGE DROPS:

V_A
20V

$$V_{R1} = 1.38\text{mA} \times 3\text{k}$$
$$= 4.16\text{V}$$

$$V_{R2} = 1.38\text{mA} \times 8\text{k}$$
$$= 11.04\text{V}$$

$$V_{R3} = 1.38\text{mA} \times 2\text{k}$$
$$= 2.76\text{V}$$

$$V_{R4} = 1.38\text{mA} \times 1.4\text{k}$$
$$= 1.93\text{V}$$

R_1

3k

R_2

8k

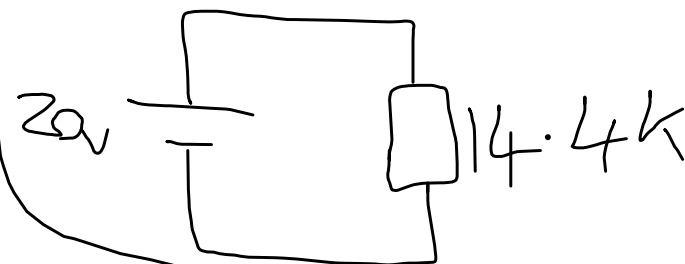
R_3

2k

R_4

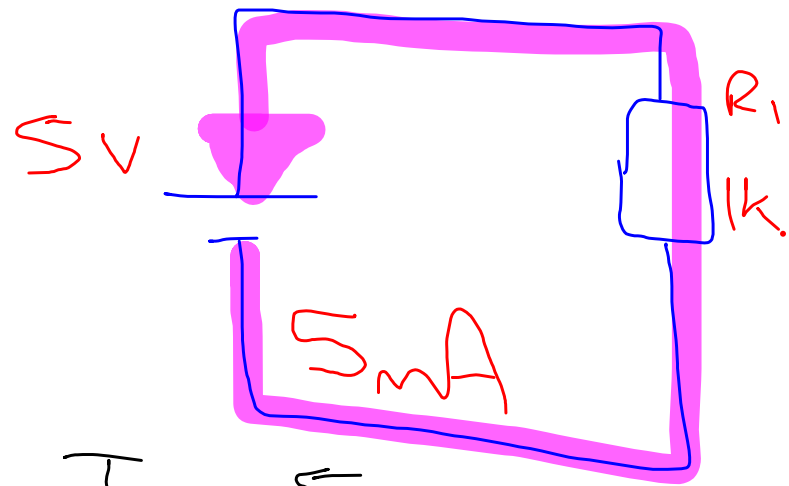
1.4k

$$R_T = 3\text{k} + 8\text{k} + 2\text{k} + 1.4\text{k}$$
$$= 14.4\text{k}$$

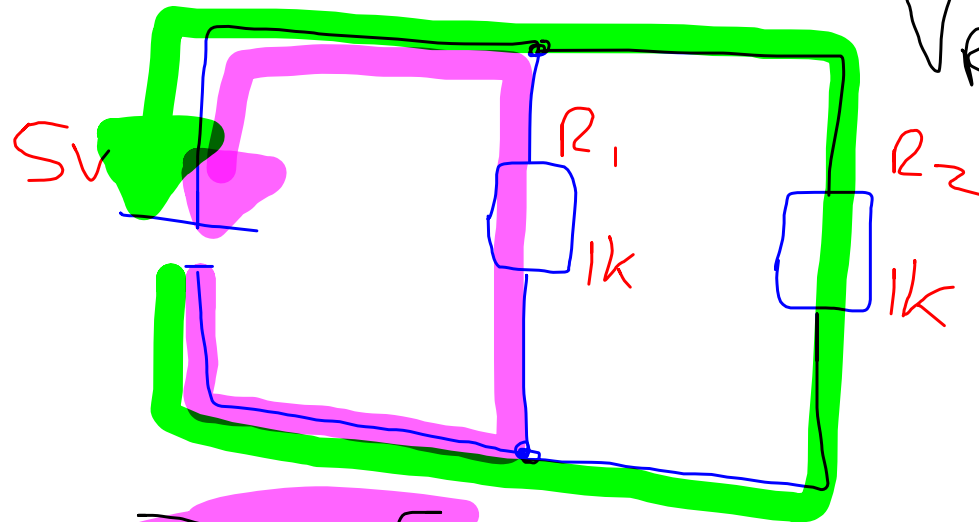


$$I_T = \frac{20\text{V}}{14.4\text{k}}$$
$$= 1.38\text{mA}$$

RESISTORS IN PARALLEL.



$$I_T = \frac{5V}{1k} = 5mA$$



$$I_{R_1} = \frac{5V}{1k} = 5mA$$

$$I_{R_2} = \frac{5V}{1k} = 5mA$$

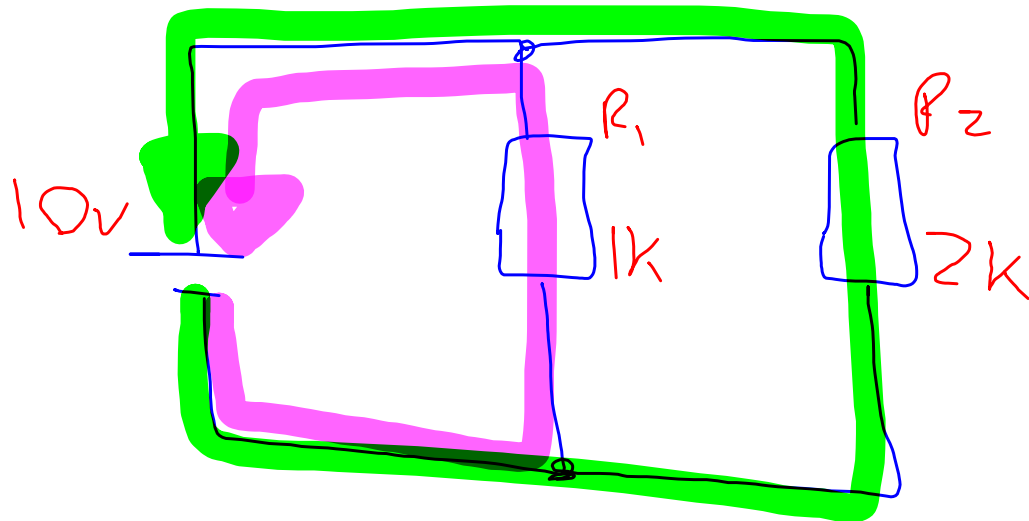
$$\begin{aligned} I_T &= I_{R_1} + I_{R_2} \\ &= 5mA + 5mA \\ &= 10mA \end{aligned}$$

$$\begin{aligned} R_T &= \frac{V_A}{I_T} \\ &= \frac{5V}{10mA} = 500\Omega \end{aligned}$$

$$V_{R_1} = 5V$$

$$V_{R_2} = 5V$$

PARALLEL STILL.

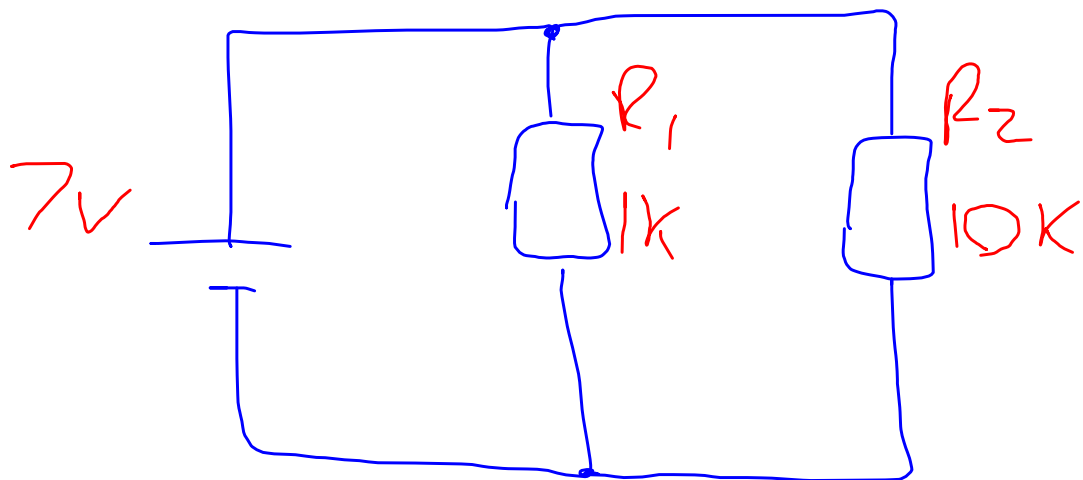


$$I_{R_1} = \frac{10V}{1k} \\ = 10mA$$

$$I_{R_2} = \frac{10V}{2k} \\ = 5mA$$

$$I_T = 10mA + 5mA \\ = 15mA$$

$$R_T = \frac{10V}{15mA} \\ = 666.67\Omega$$



$$I_{R1} = \frac{7V}{1k}$$
$$= 7mA$$

$$I_{R2} = \frac{7V}{10k}$$
$$= 700\mu A$$

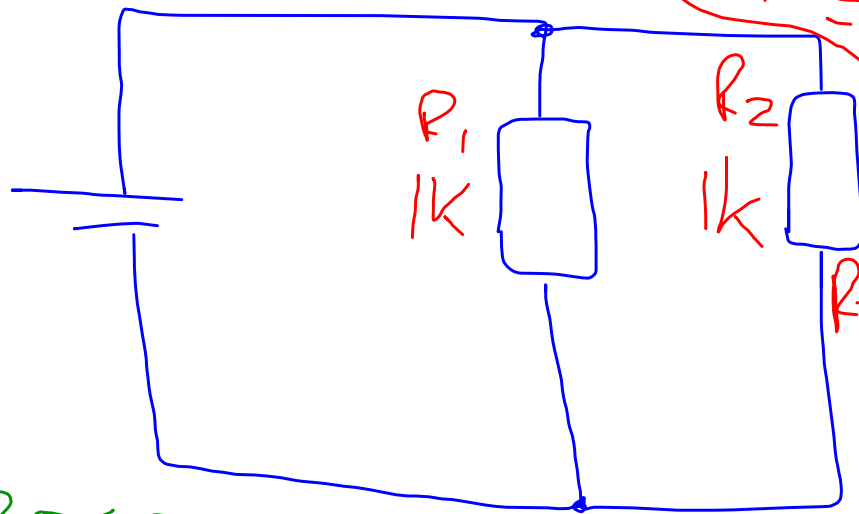
$$I_T = 7mA + 700\mu A$$
$$= 7.7mA$$

$$R_T = \frac{7V}{7.7mA}$$
$$= 909.09\Omega$$

FINDING

R_T (AKA R_E)

$R_T = \frac{\text{PRODUCT}}{\text{SUM}}$ METHOD



RECIPROCAL METHOD.

$$R_T = \frac{1}{\frac{1}{R_1} + \frac{1}{R_2} + \frac{1}{R_{\text{WHATEVER}}}}$$

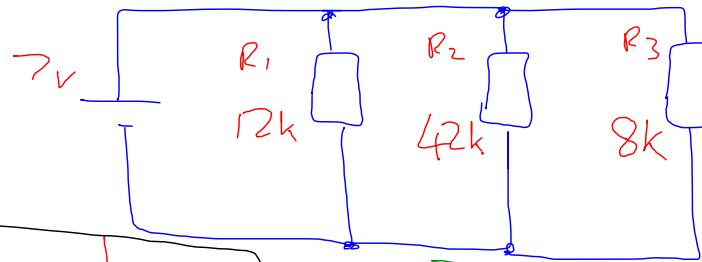
$$R_T = \frac{1}{\frac{1}{1k} + \frac{1}{1k}} = 500\Omega$$

$$R_T = \frac{R_1 \times R_2}{R_1 + R_2}$$

$$R_T = \frac{1k \times 1k}{1k + 1k}$$

$$R_T = \frac{1M}{2k}$$

$$= 500\Omega$$



$$R_T = \frac{1}{\frac{1}{12k} + \frac{1}{42k} + \frac{1}{8k}}$$

$$= 4.31k$$

$$I_T = \frac{7V}{4.31k}$$

$$= 1.63mA$$

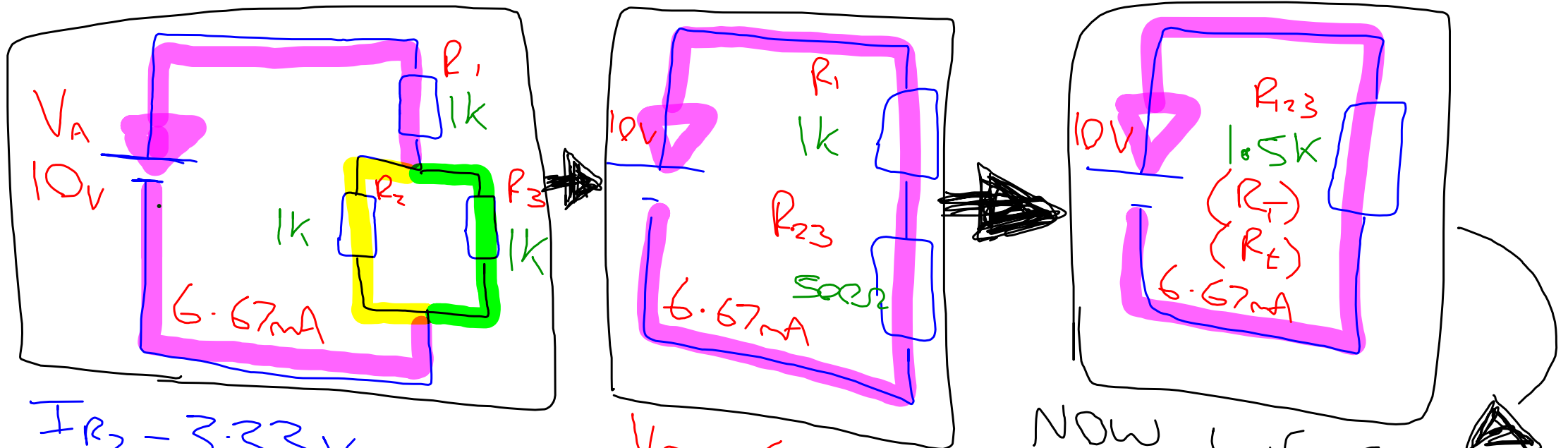
$$I_{R1} = \frac{7V}{12k} = 583.3\mu A$$

$$I_{R2} = \frac{7V}{42k} = 166.67\mu A$$

$$I_{R3} = \frac{7V}{8k} = 875\mu A$$

$$I_T = 1.62mA$$

SERIES / PARALLEL.



$$I_{R_2} = \frac{3.33V}{1k} = 3.33mA$$

$$I_{R_3} = \frac{3.33V}{1k} = 3.33mA$$

$$I_{R_1} = \frac{6.67V}{1k} = 6.67mA$$

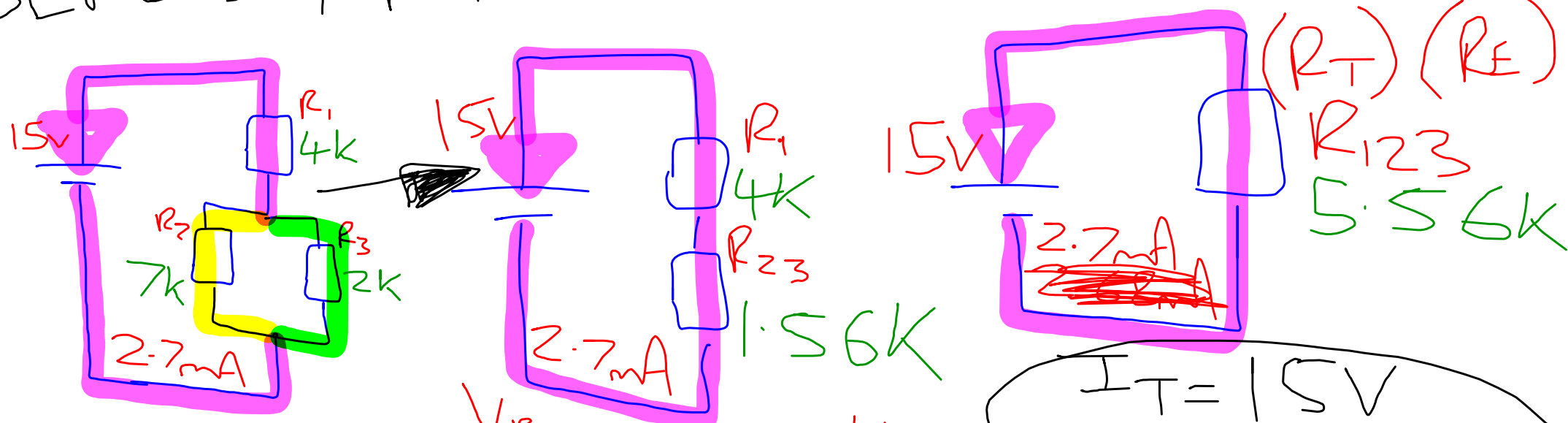
$$V_{R_1} = 6.67mA \times 1k = 6.67V$$

$$V_{R_{23}} = 6.67mA \times 500 = 3.33V$$

NOW WE CAN FIND I_T

$$I_T = \frac{10V}{1.5k} = 6.67mA$$

SERIES / PARALLEL.



$$V_{R1} = 2.7mA \times 4k$$

$$= 10.81V$$

$$V_{R2} = 2.7mA \times 1.56k$$

$$= 4.19V$$

$$I_{R2} = \frac{4.19V}{7k}$$

$$= 598.57\mu A$$

$$I_{R3} = \frac{4.19V}{2k}$$

$$= 2.09mA$$

$$I_T = \frac{15V}{5.56k}$$

$$= 2.7mA$$

$$I_{R1} = \frac{10.81V}{4k}$$

$$= 2.7mA$$

V_{R1}
 V_{R2}
 V_{R3}
 I_{R1}
 I_{R2}
 I_{R3}

SERIES / PARALLEL



$$V_{R1} = I_{R1} \times R_1$$

$$= 74.12 \text{mA} \times 100 \Omega$$

$$= 7.41 \text{V}$$

$$V_{R23} = I_{R23} \times R_{23}$$

$$= 74.12 \text{mA} \times 142.86 \Omega$$

$$= 10.59 \text{V}$$

$$R_{23} = \frac{1}{\frac{1}{200} + \frac{1}{500}}$$

$$= 142.86 \Omega$$

$$R_T = 142.86 + 100$$

$$= 242.86 \Omega$$

$$I_T = \frac{18 \text{V}}{242.86 \Omega}$$

$$= 74.12 \text{mA}$$

$$I_{R2} = \frac{V_{R2}}{R_2}$$

$$= \frac{10.59 \text{V}}{200 \Omega}$$

$$= 52.94 \text{mA}$$

$$I_{R3} = \frac{V_{R3}}{R_3}$$

$$= \frac{10.59 \text{V}}{500 \Omega}$$

$$= 21.18 \text{mA}$$

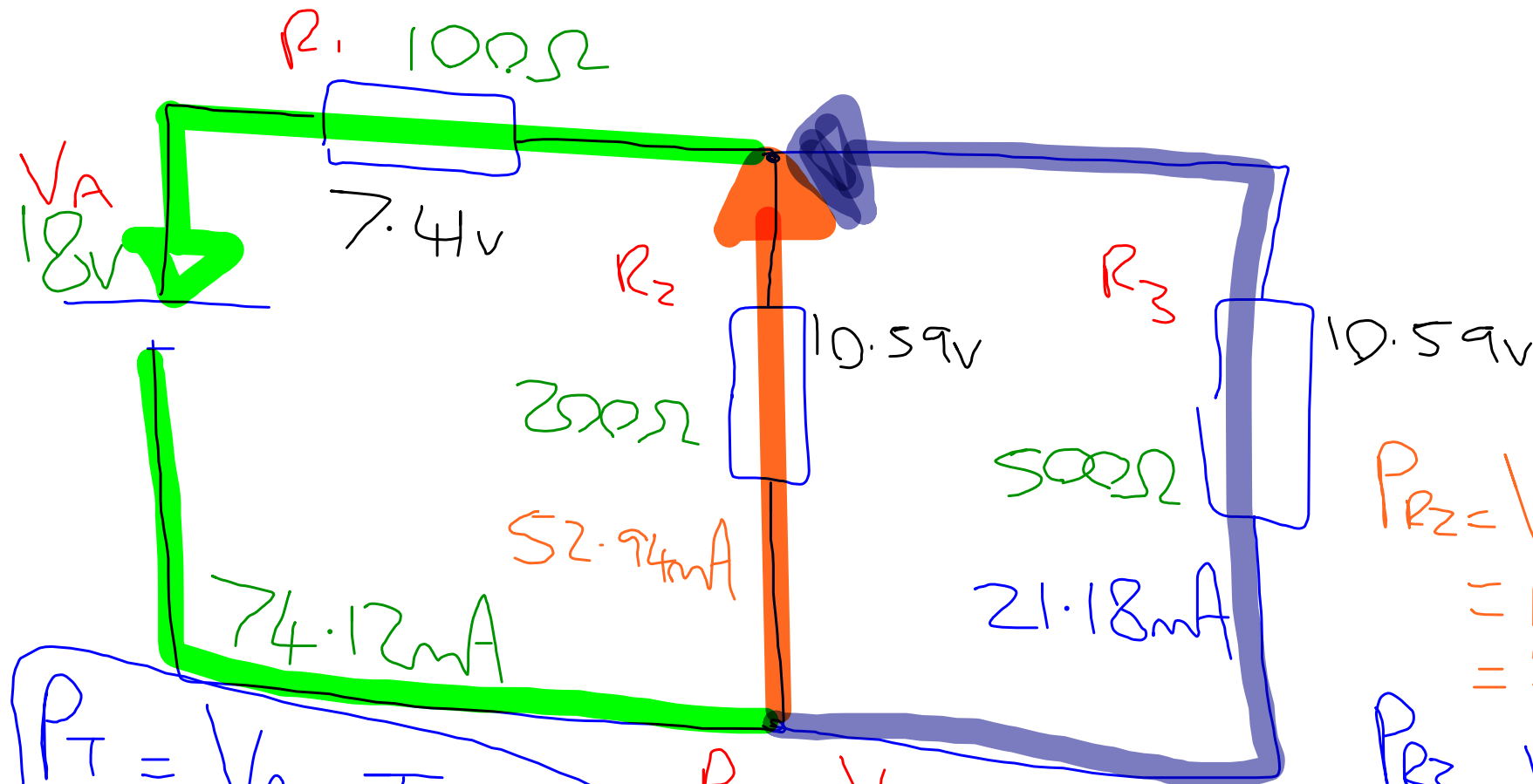
Find:
 R_T
 I_T
 V_{R23}
 V_{R1}
 I_{R2}
 I_{R3}

in order to find all these values, you need to first find the total (or equivalent) resistance. firstly you need to put R_2 and R_3 in parallel. (we call this R_{23}) then you place this resistance in series with R_1 (we call this R_T or R_{123}).

Now you have the total resistance, you can find the total current $I_T = V_A / R_T$

Then you can use this current to find the voltage across R_1 and R_{23} . then you can find the current through R_2 and R_3 . (see previous pages for further help)

NOW LETS WORK OUT POWER FOR THE CIRCUIT ON THE PREVIOUS PAGE



$$\begin{aligned}
 P_{R2} &= V_{R2} \times I_{R2} \\
 &= 10.59V \times 52.94mA \\
 &= 560.64mW
 \end{aligned}$$

$$\begin{aligned}
 P_{R3} &= V_{R3} \times I_{R3} \\
 &= 10.59V \times 21.18mA \\
 &= 224.3mW
 \end{aligned}$$

$$\begin{aligned}
 P_{R1} &= V_{R1} \times I_{R1} \\
 &= 7.41V \times 74.12mA \\
 &= 549.23mW
 \end{aligned}$$

$$P_T = P_{R1} + P_{R2} + P_{R3}$$

$$P = 549.23mW + 560.64mW + 224.3mW = 1.33W$$

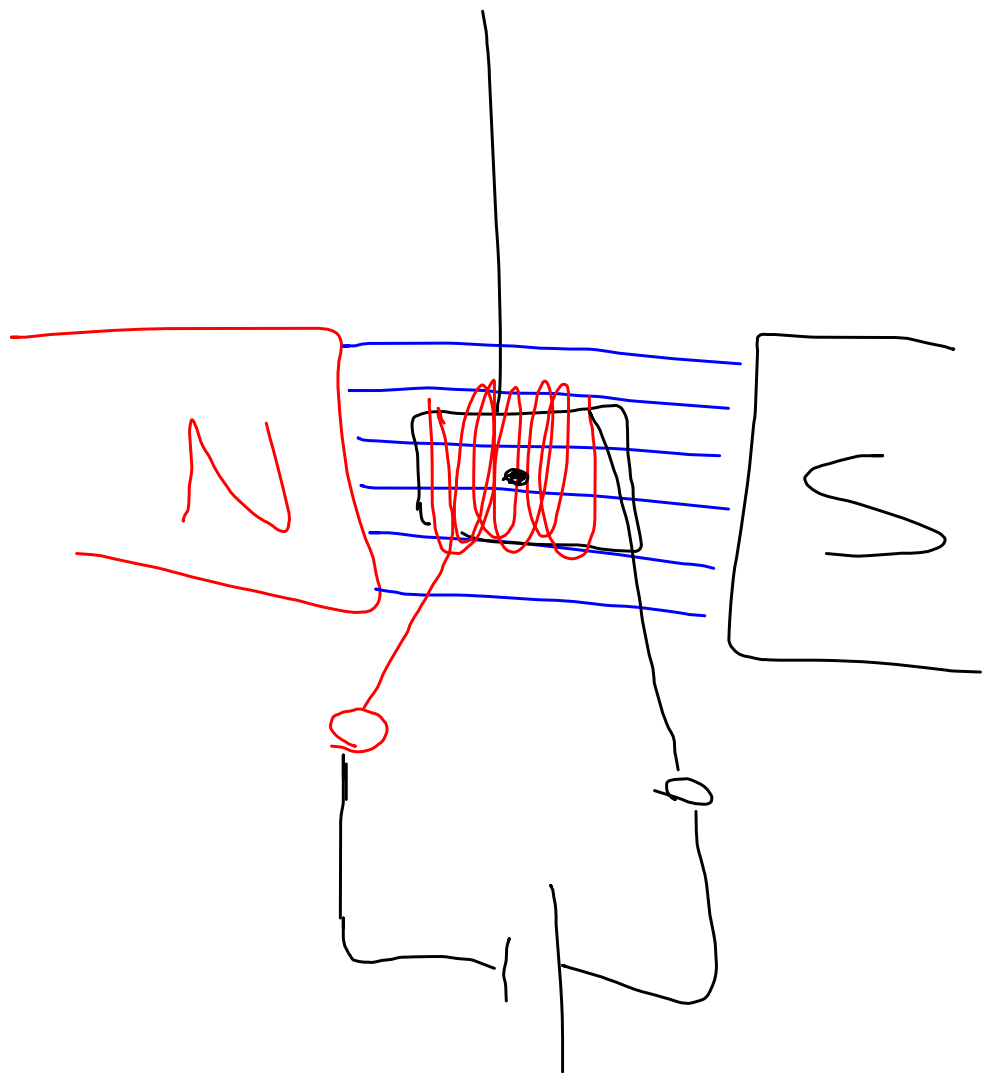
$$\begin{aligned}
 P_T &= V_A \times I_T \\
 &= 18V \times 74.12mA \\
 &= 1.33W
 \end{aligned}$$

VARIOUS WAYS TO CALCULATE
POWER.

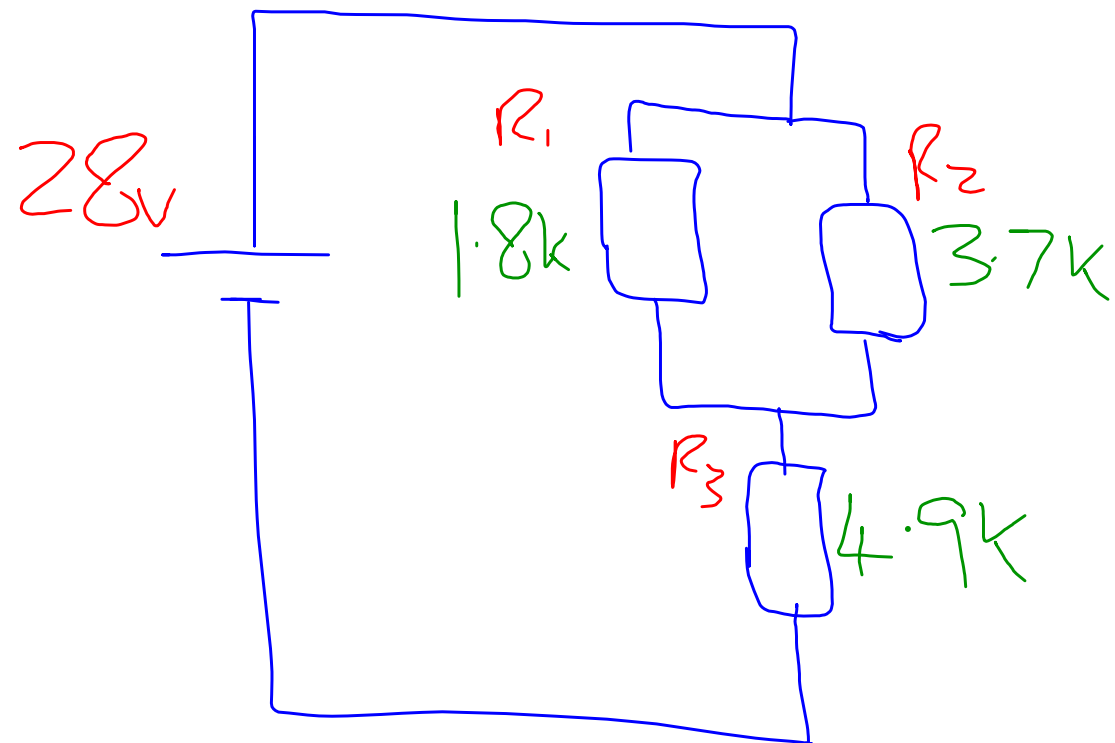
$$P = V \times I$$

$$P = I^2 R$$

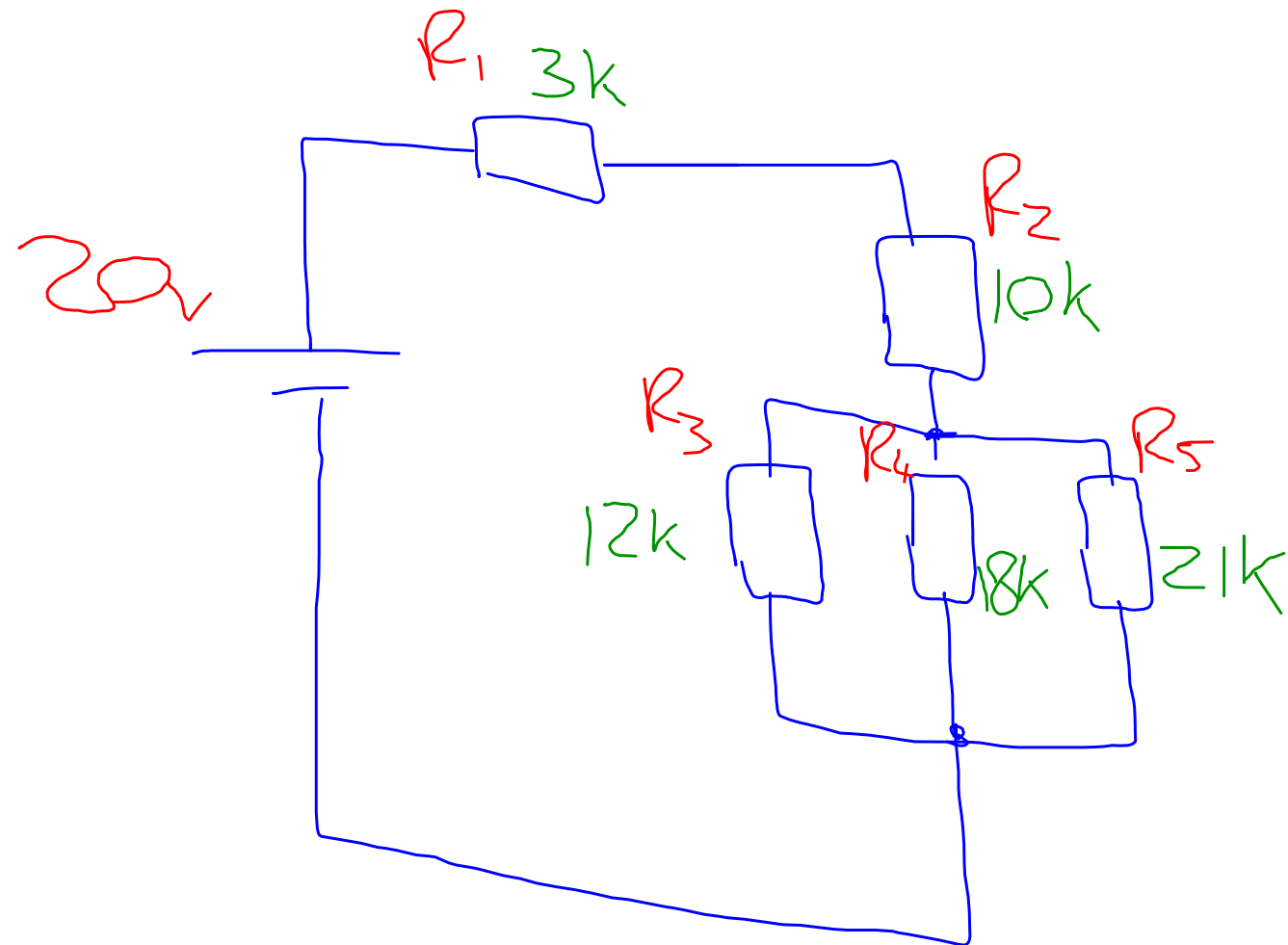
$$P = \frac{V^2}{R}$$



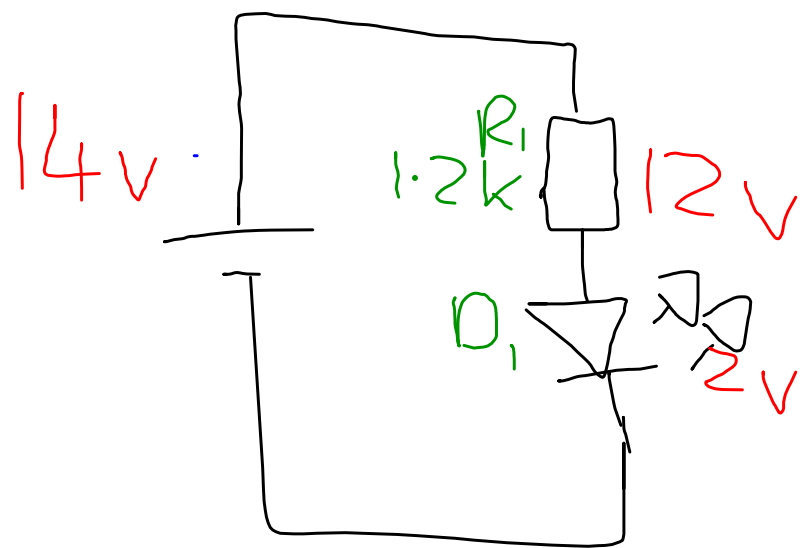
FIND THE SAME VALUES AS THE PREVIOUS PAGE.



A MORE DIFFICULT CIRCUIT...
FIND VOLTAGE DROPS + CURRENT FOR
ALL RESISTORS.



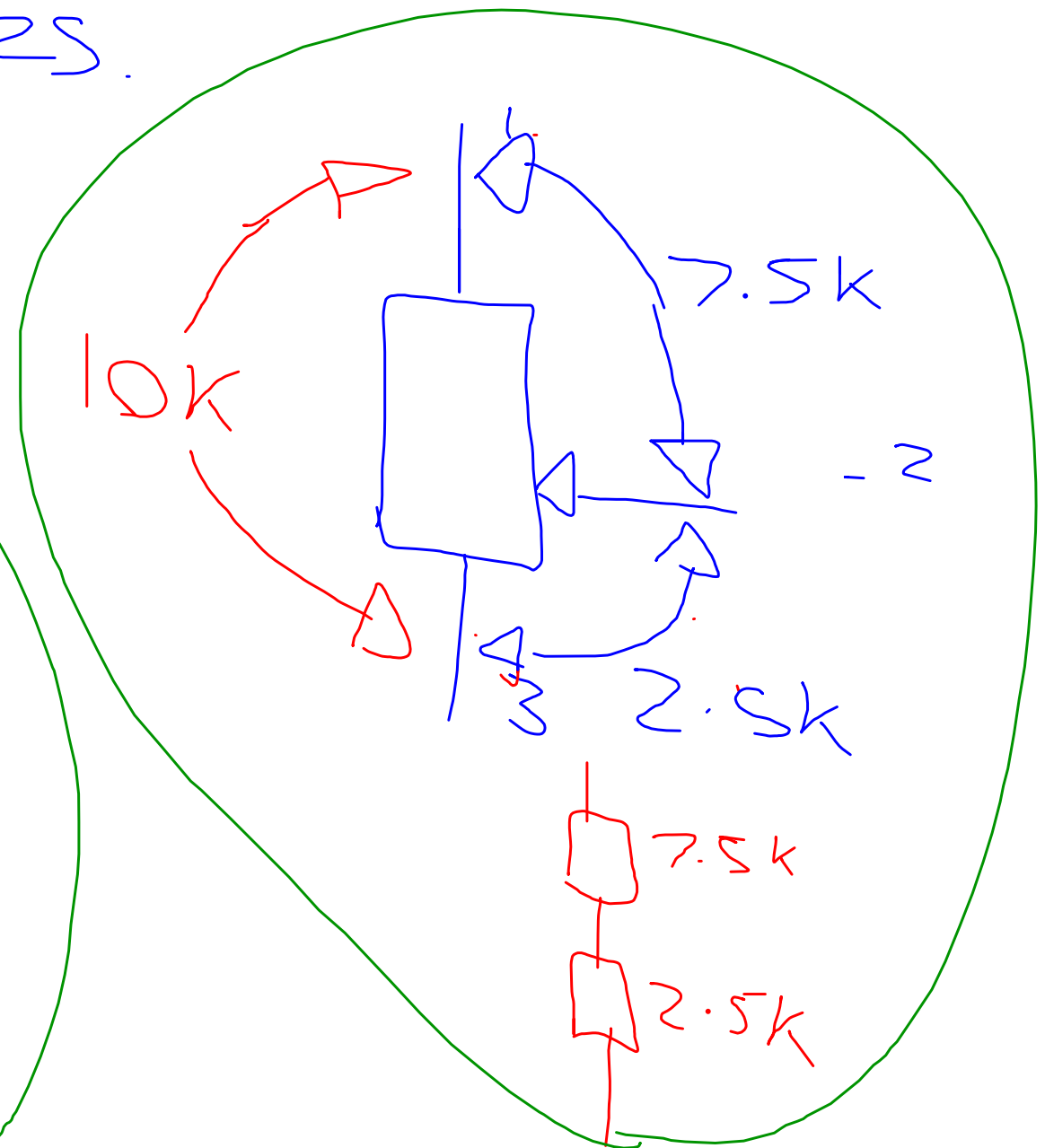
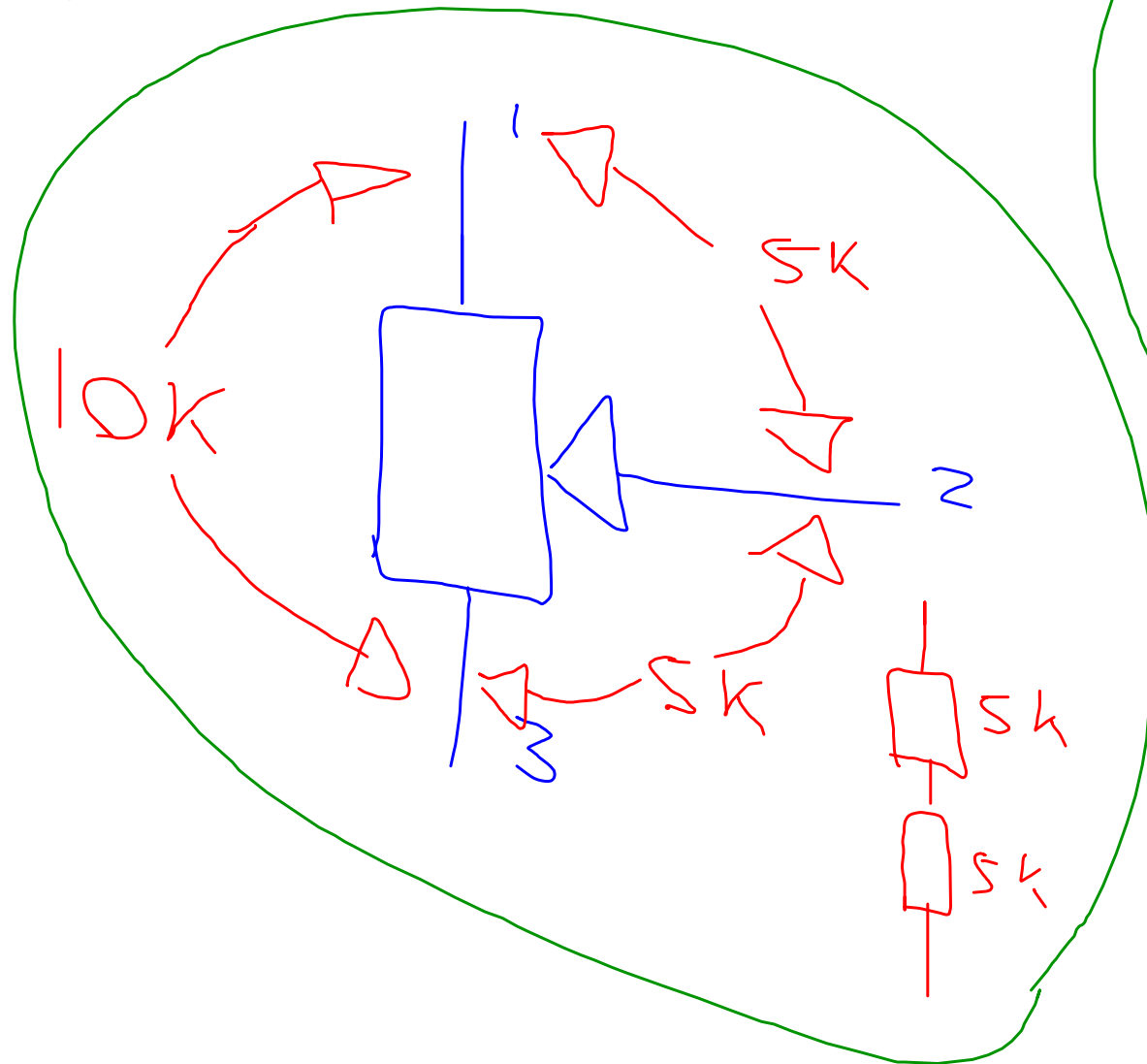
DESIGN A ^{SERIES} CIRCUIT THAT
HAS 10mA OF CURRENT
FLOWING. THE CIRCUIT HAS A
14V BATTERY AND A 2V LED



$$\begin{aligned} R_1 &= \frac{V_{R_1}}{I_{R_1}} \\ &= \frac{12V}{10mA} \\ &= 1.2k\Omega \end{aligned}$$

POTENTIOMETERS.

3 connections.



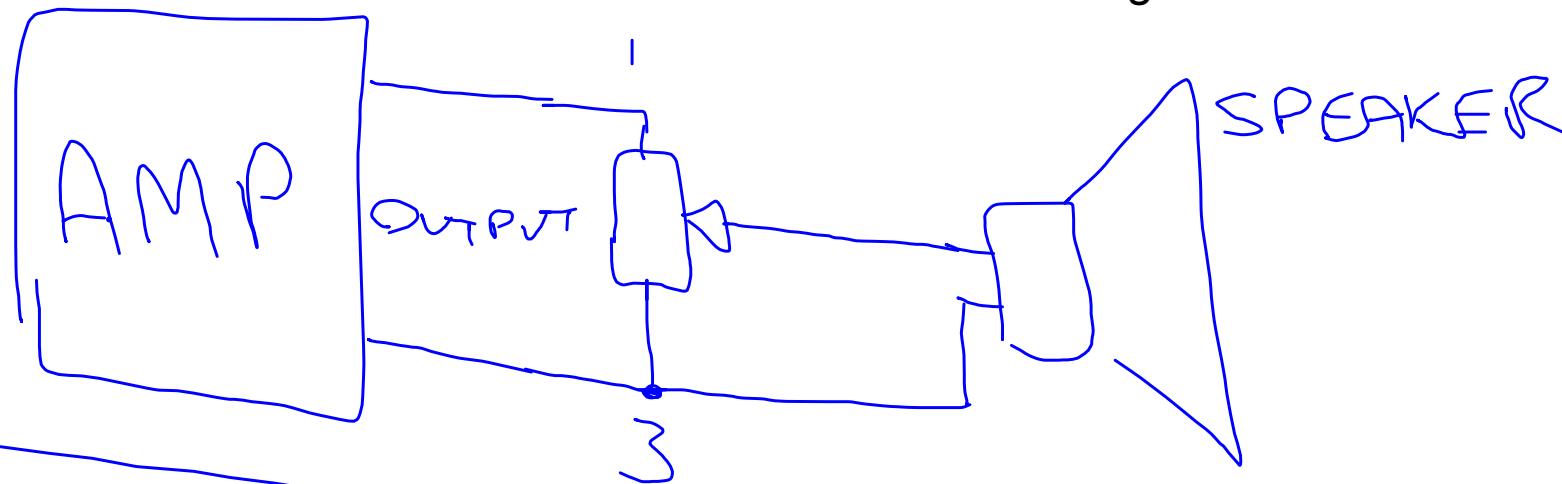
potentiometers are a three terminal device. between the top and bottom terminal we essentially have a fixed amount of resistance (just like any other fixed resistor) however now we have a third connection which is known as the wiper arm. this wiper arm can move all the way from one side of the resistor to the other. It acts just like two resistors in series. as we move the wiper arm more towards the bottom terminal, the resistance between the wiper arm and the bottom terminal will decrease while the resistance between the wiper arm and top terminal will increase and vice versa.

We normally aren't concerned with the resistance of a potentiometer, but rather the voltage we can get out from it. hopefully you will recall that resistance ratios and voltage ratios are the same. If we now connect 10v between the top and bottom terminals of a potentiometer, we can then move the wiper arm up or down to 'pickoff' more or less voltage. See next pages for examples.

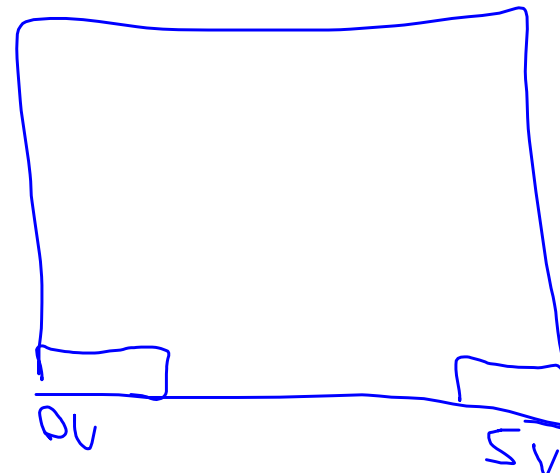
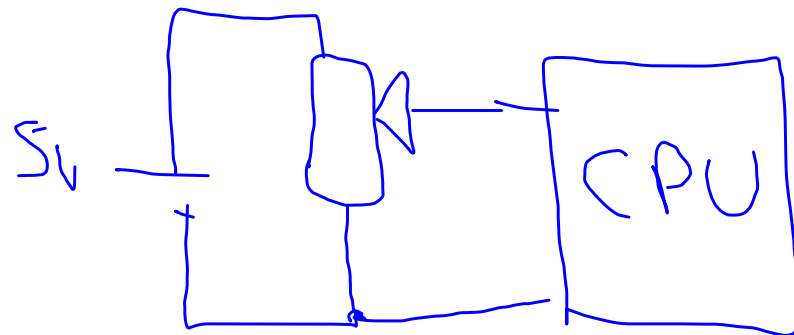
USES OF POTS.

TOTAL O/P
= 10V

we can use pots as volume control. the higher we move the wiper arm, the more voltage we will feed through to the speaker which means the louder it will get.

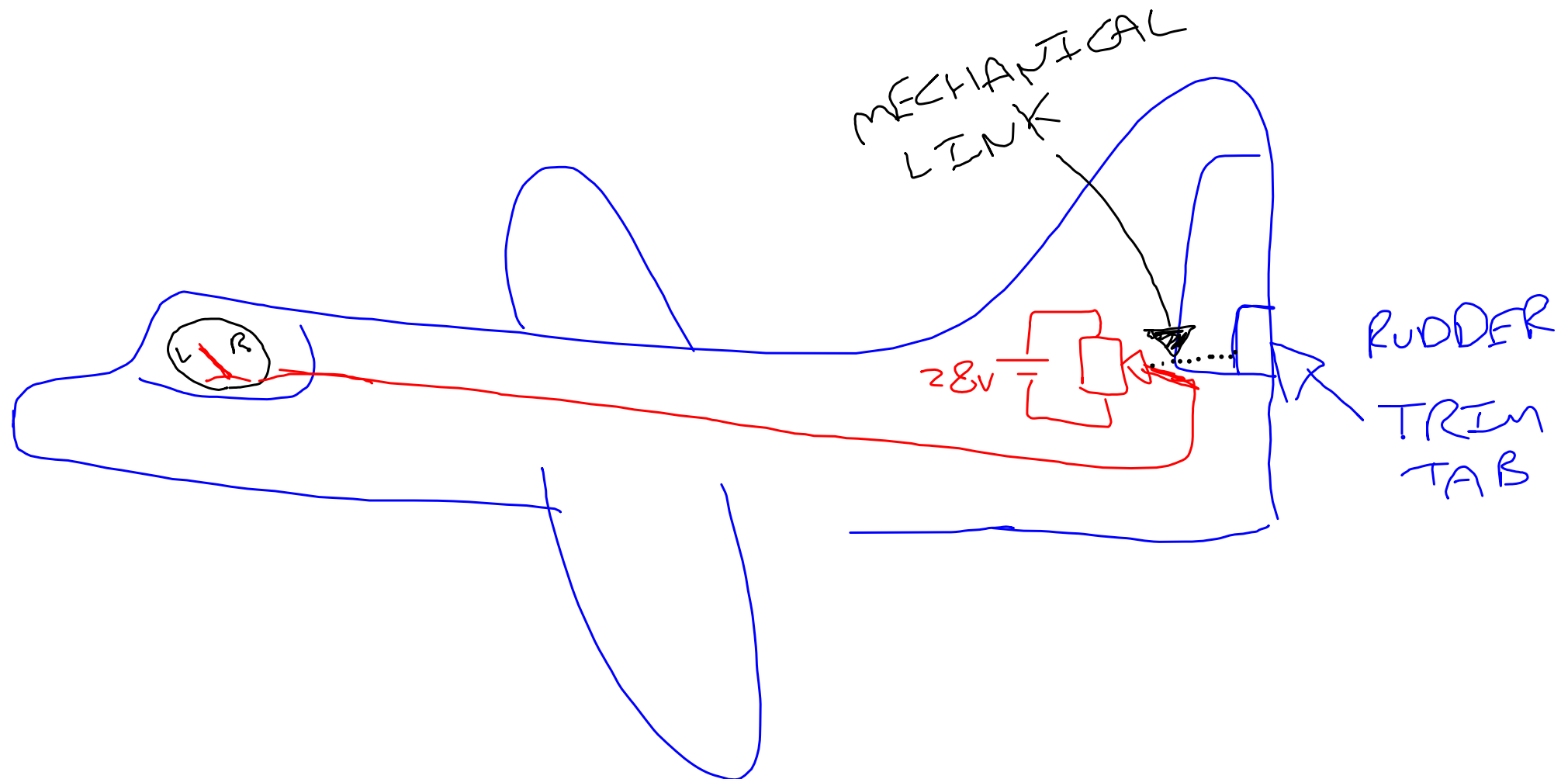


USED IN RETROBALL.



we can also use pots in retroball. This is where we can pick off a certain voltage, send it to the CPU which will then move the paddle to a certain place on the screen. 0v would be all the way to the left, 2.5v would be in the middle, 5v would be all the way to the right etc...

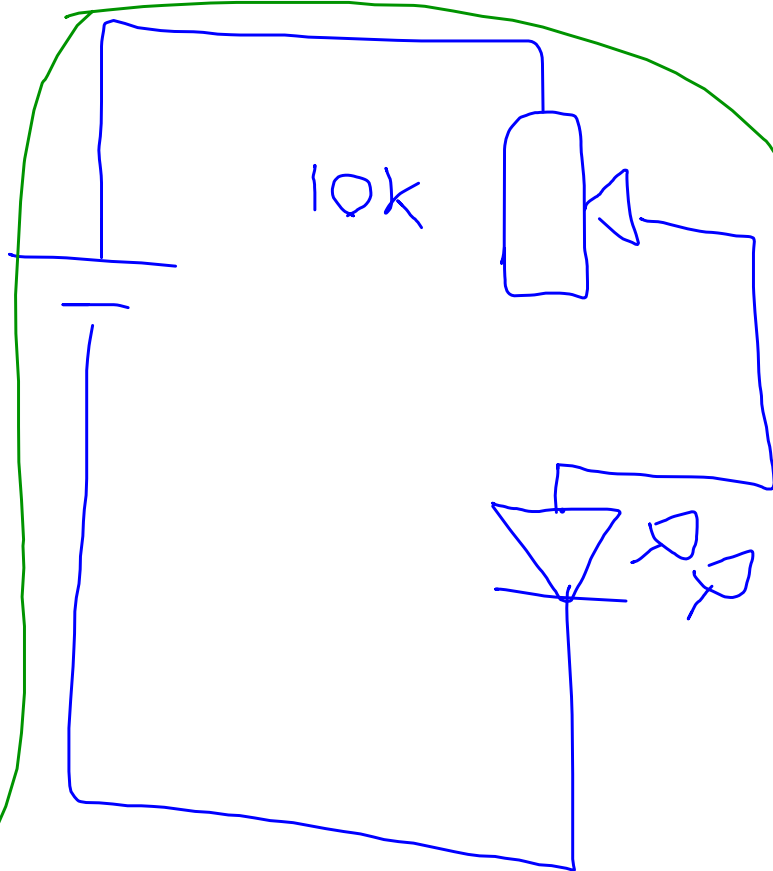
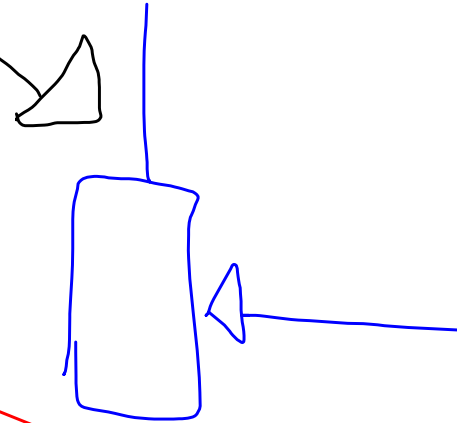
ONE LAST USE.



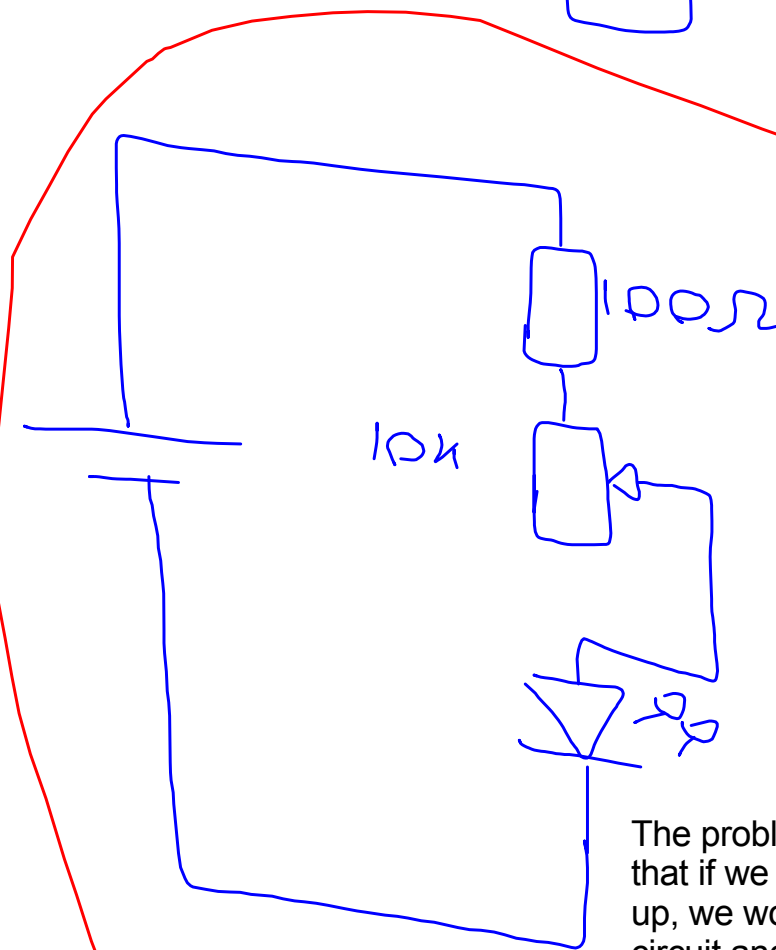
Here we have a rudder trim tab system. The pilot can move this trim tab to the left and right. The pilot would then like some feedback as to where his trim tab is. We have a potentiometer connected to the trim tab, as the trim tab moves, it rotates the potentiometer, moving the wiper arm closer to 28v or closer to 0v. this voltage is fed back to the cockpit where it is connected to an indicator. For example, 0v would be trim tab fully left, 14v would be trim tab in the middle and 28v would be trim tab fully right.

RHEOSTAT

a rheostat has two connections. We use these where all we want to do is vary the resistance (most probably to vary the current in a circuit to make a light bulb brighter / dimmer for example...)



the further we move the wiper arm up, the less resistance and therefore the brighter the LED in this circuit.



The problem with the circuit on the left is that if we moved the wiper arm all the way up, we would have no resistance in the circuit and would not be limiting current which means we would burn out the LED. to make sure that the circuit resistance is never 0 ohms, we normally place a fixed resistor in series with the rheostat. now when the rheostat is at 0 ohms, we will still have the fixed resistor in the circuit to limit the current.

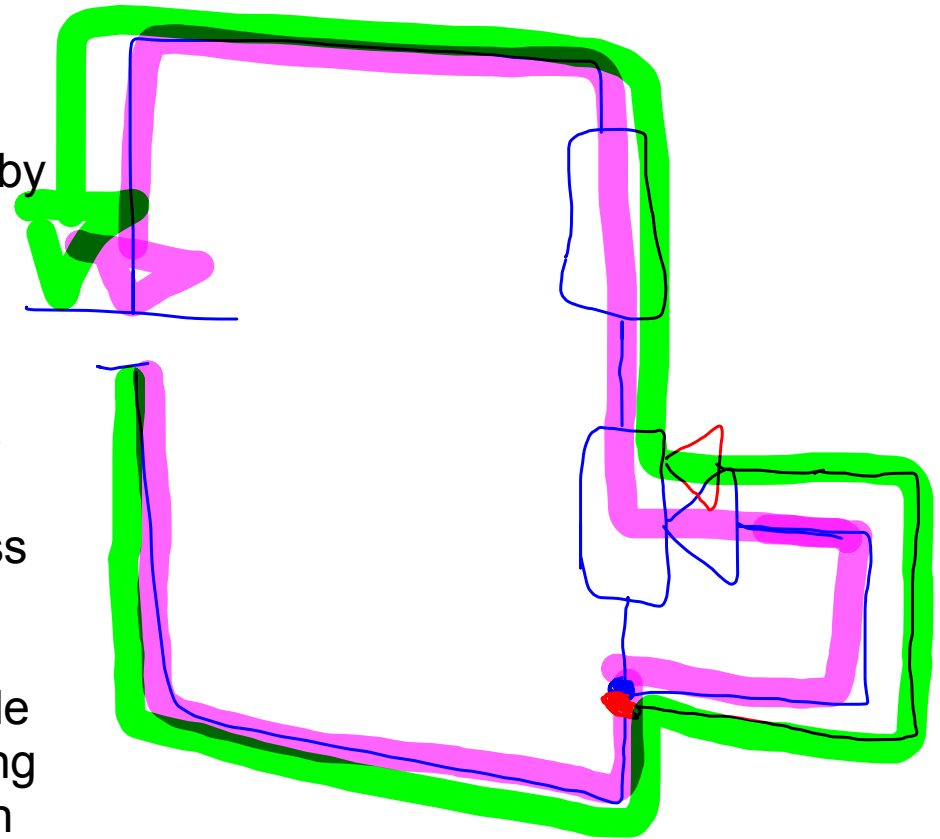
ANOTHER WAY TO MAKE A RHEOSTAT.

here we have made a rheostat out of a potentiometer by connecting the wiper arm to one of the fixed resistor connections.

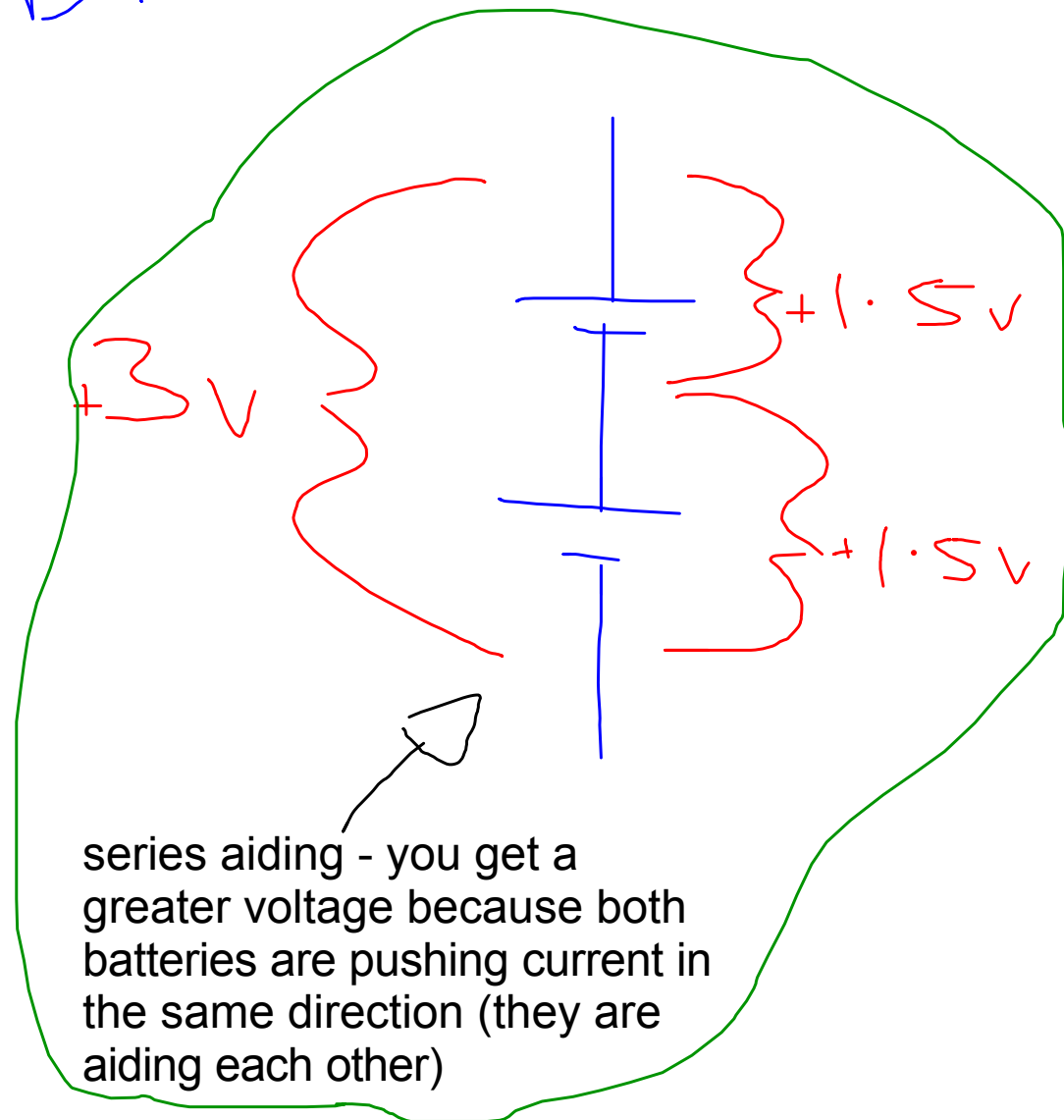
The green highlighter shows the current flow with the wiper arm near the top of the potentiometer. Since the wiper arm is connected to the bottom of the potentiometer, we have essentially been able to bypass most of the resistor, therefor the resistance is less.

The pink highlighter shows the current flow in the middle of the potentiometer. This means we are only bypassing half the resistor therefor there is more resistance when compared to the green highlighter.

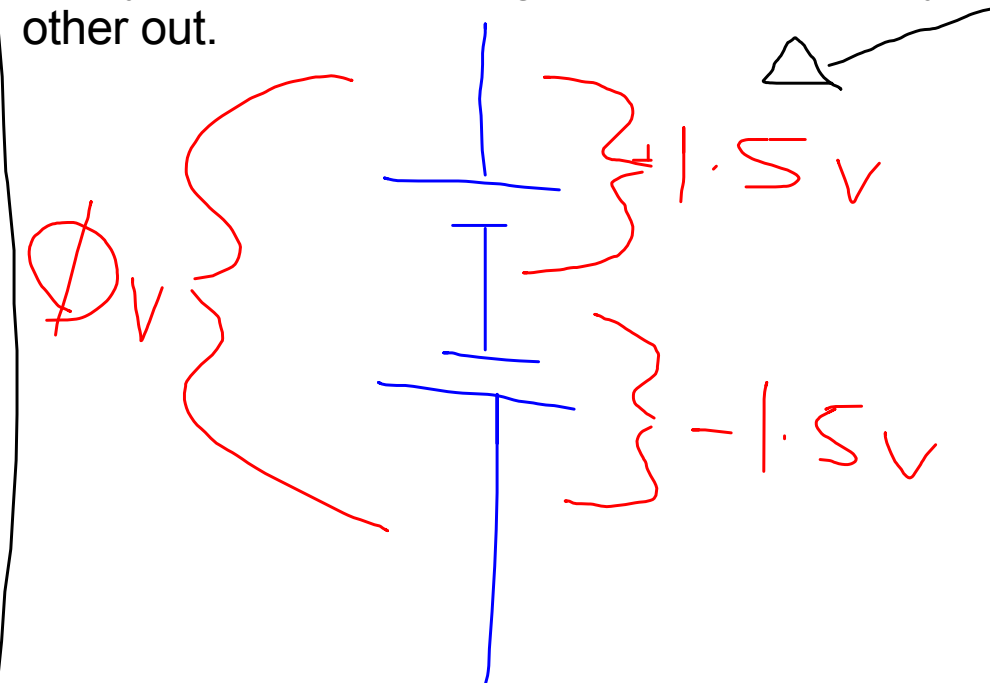
We will get maximum resistance from this by moving the wiper arm all the way down the bottom of the potentiometer. This will mean that the current does not bypass any of the resistance, it has to flow through the whole thing.



BATTERIES (CELLS) SERIES.

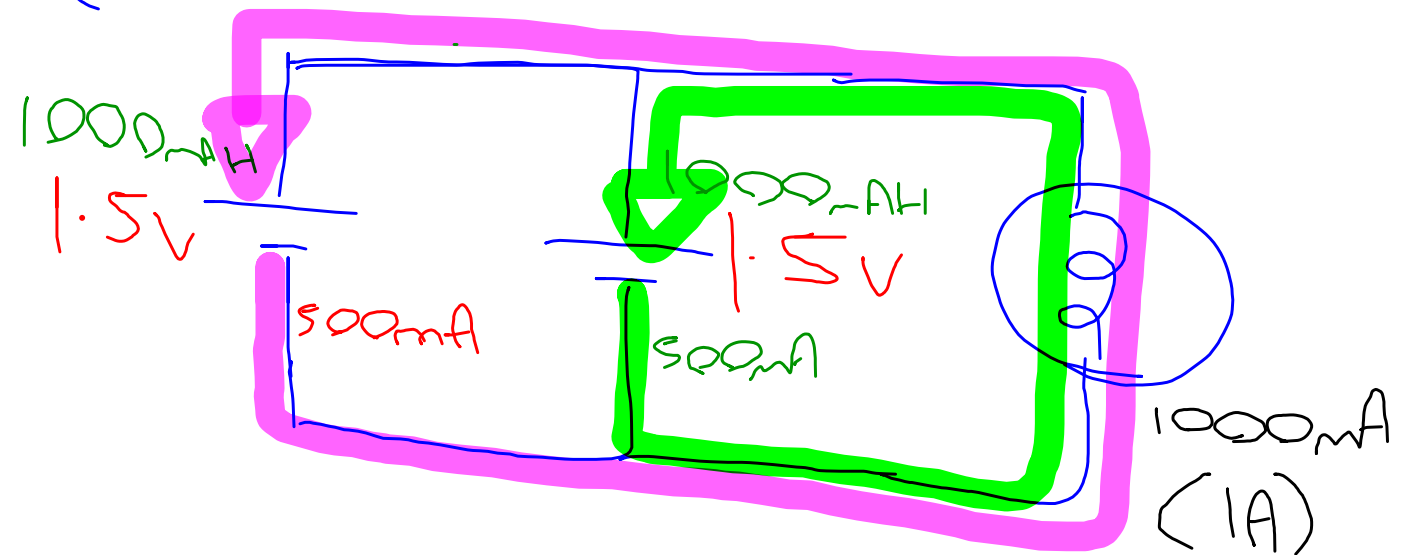


series opposing, both batteries are pushing current in the opposite direction (they are opposing each other) therefore if they are both as strong as each other, they cancel each other out.



if one battery is pushing harder than the other, in the opposite direction, then this battery will win and current will flow but the voltage (pushing force) will be less than if the battery did not have the opposing battery to contend with.

PARALLEL (BATTERIES)



connecting batteries in parallel does not change the voltage but it does give us a greater current capability. Basically this means that if we had one 1.5v 1000mAh battery that was powering a circuit with a current draw of 1000mA, this one battery would last for 1 hour.

If we placed a second identical battery in parallel with the first, we have increased the current capability. This means that if the circuit was to draw 1000mA, the circuit would now be powered for 2 hours instead of just 1 hour.

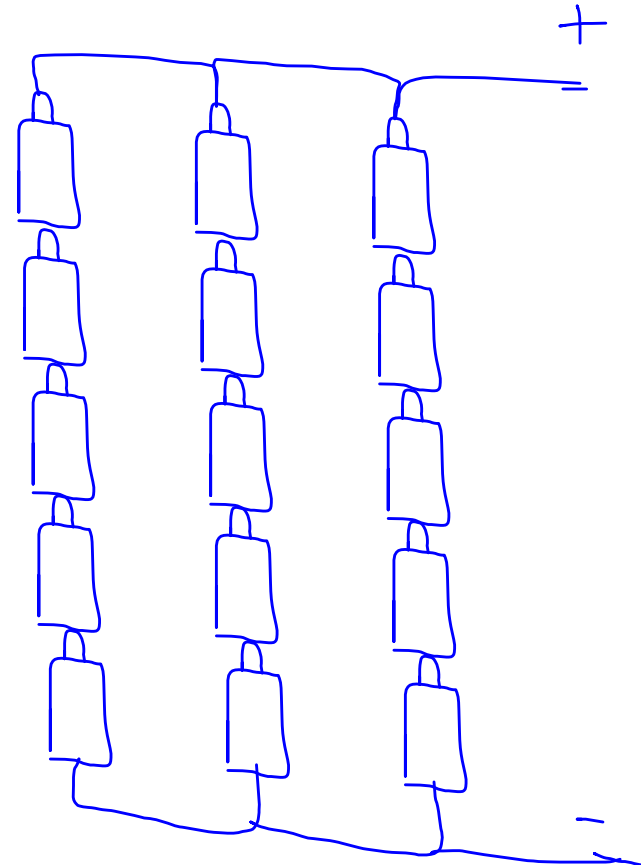
Essentially, the light bulb will draw half of its current from each battery (I.E. 500mA from each.) Instead of the full 1000mA from just one battery.

SERIES / PARALLEL.

lets make a 6V 3000mAh (3Ah) battery pack out of individual 1.2V 1000mAh (1Ah) batteries.

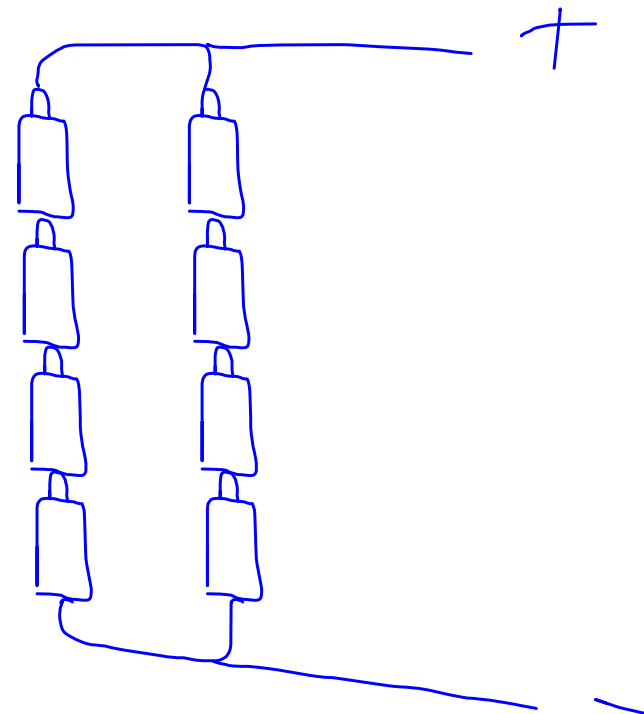
We make laptop batteries in this fashion I.E. a laptop battery pack is made of lots of smaller batteries connected in series / parallel.

when we connect batteries in series, we increase the voltage. when we connect batteries in parallel, we increase their current capacity. Remember it's not the battery that tells the circuit how much current will flow but rather the circuit will draw a certain amount of current depending on its resistance.



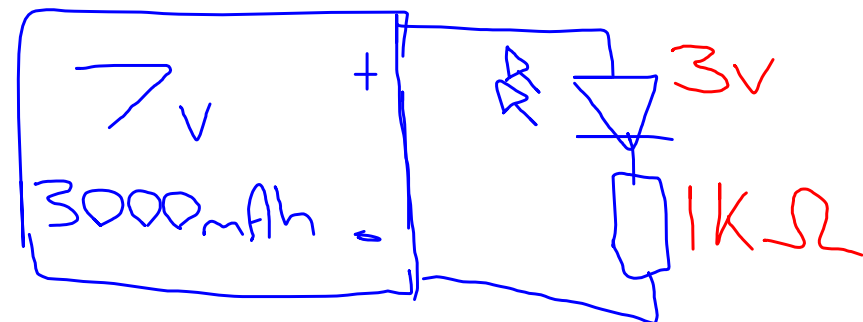
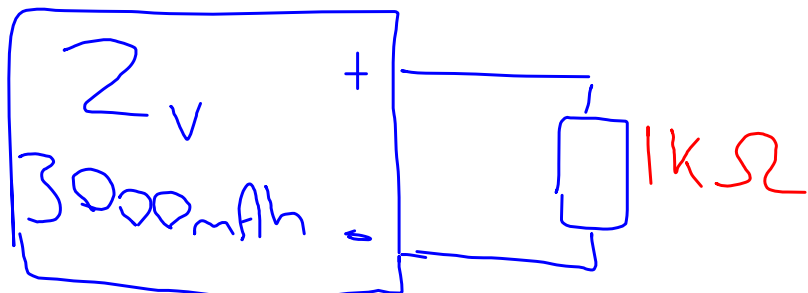
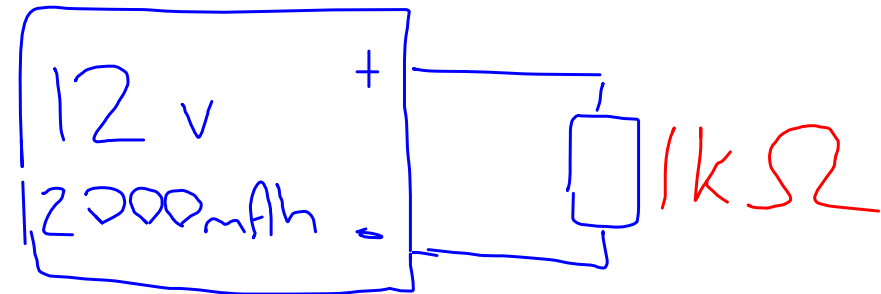
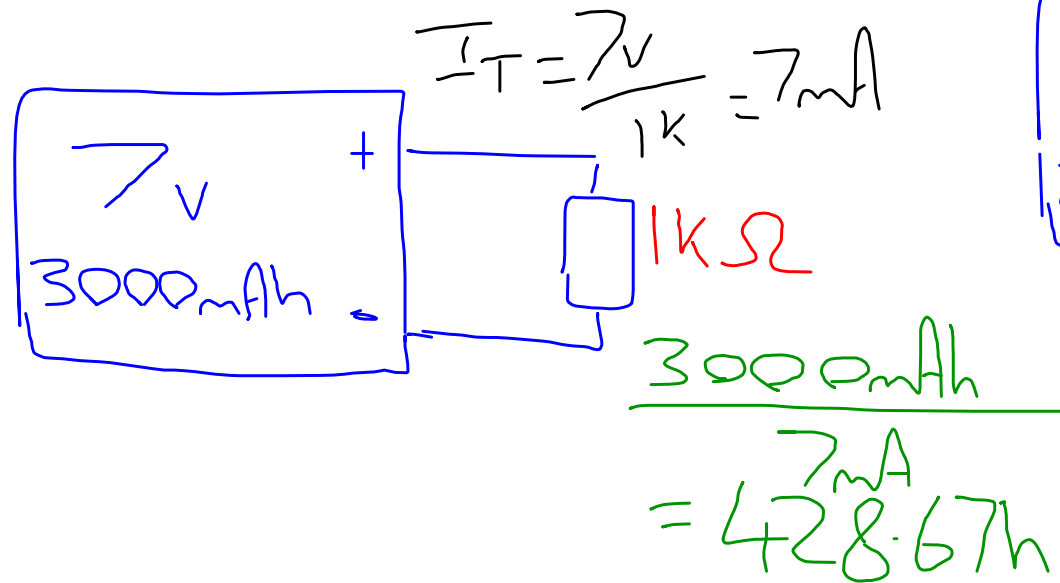
BATTERIES CONTINUED...

draw up a battery pack that would give us 8v 4000mAh
from individual cells that are 2v 2000mAh



Now do one that would give us 15v 2400mAh from
individual cells that are 3v 800mAh

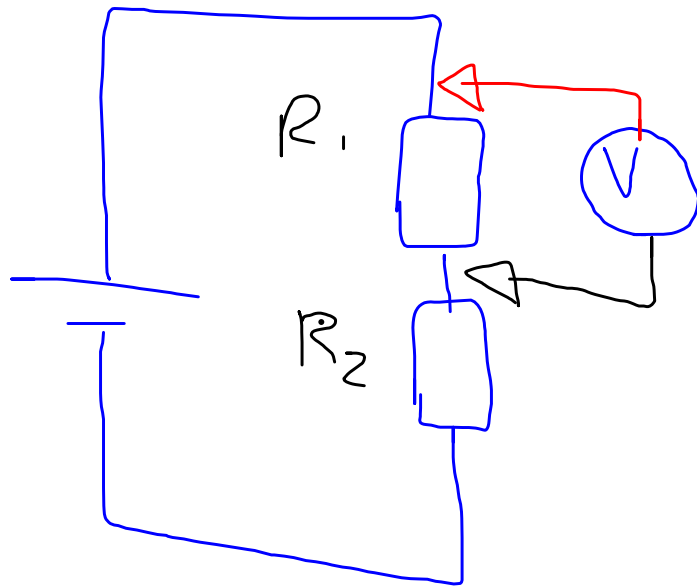
how long would it take for these battery packs to die?



CONNECTING METERS.

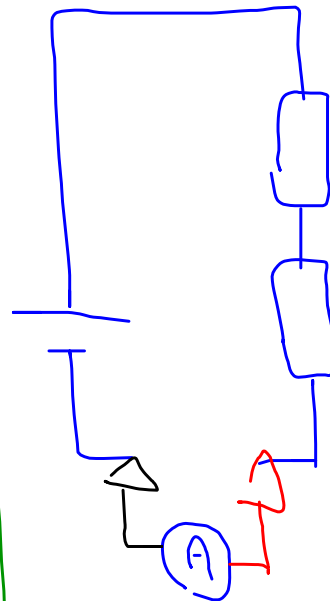
A multimeter has 3 main functions. VOLTAGE - CURRENT- RESISTANCE

VOLTAGE



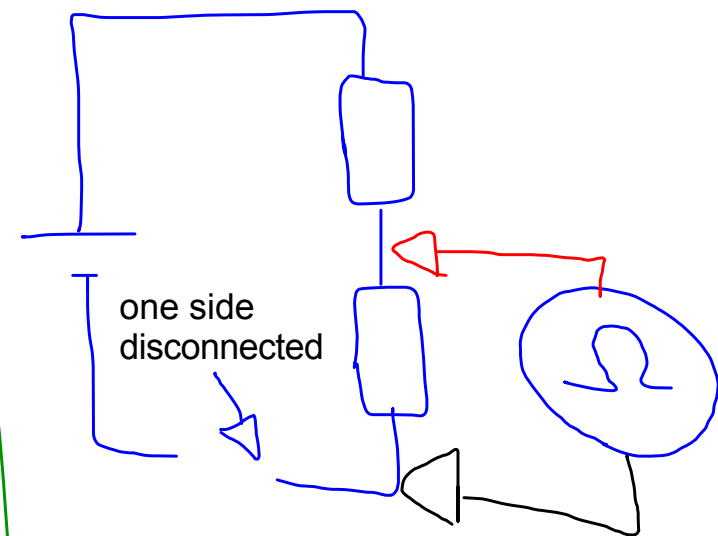
To measure voltage you place the leads directly across a component I.E. in parallel with the component. power needs to be ON.

CURRENT



To measure current, you need to make an open circuit somewhere, then place your ammeter in series with the circuit. (this is because we want all the current in the circuit to flow through the meter. Power needs to be ON.

RESISTANCE.

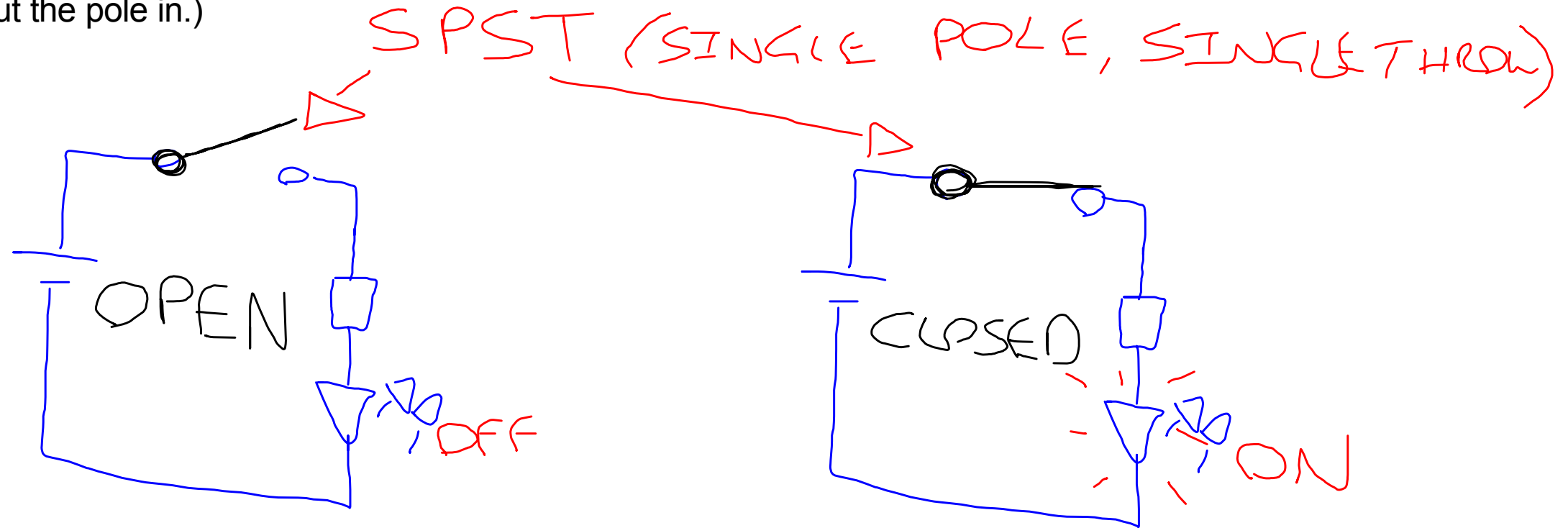


To measure resistance, you need to make sure that at least one side of the resistor is disconnected from the circuit. The connect the ohmmeter across the resistor you are checking. I.E. in parallel with the component. Power needs to be off because the ohmmeter will use it's own internal power supply, your reading will be inaccurate if you include the circuit power supply also.

The reason we need to make sure that at least one side of the resistor is disconnected from the circuit is so that we don't create an extra current path for the current flowing from the meters power supply. if we get an alternate current path, our reading will be inaccurate.

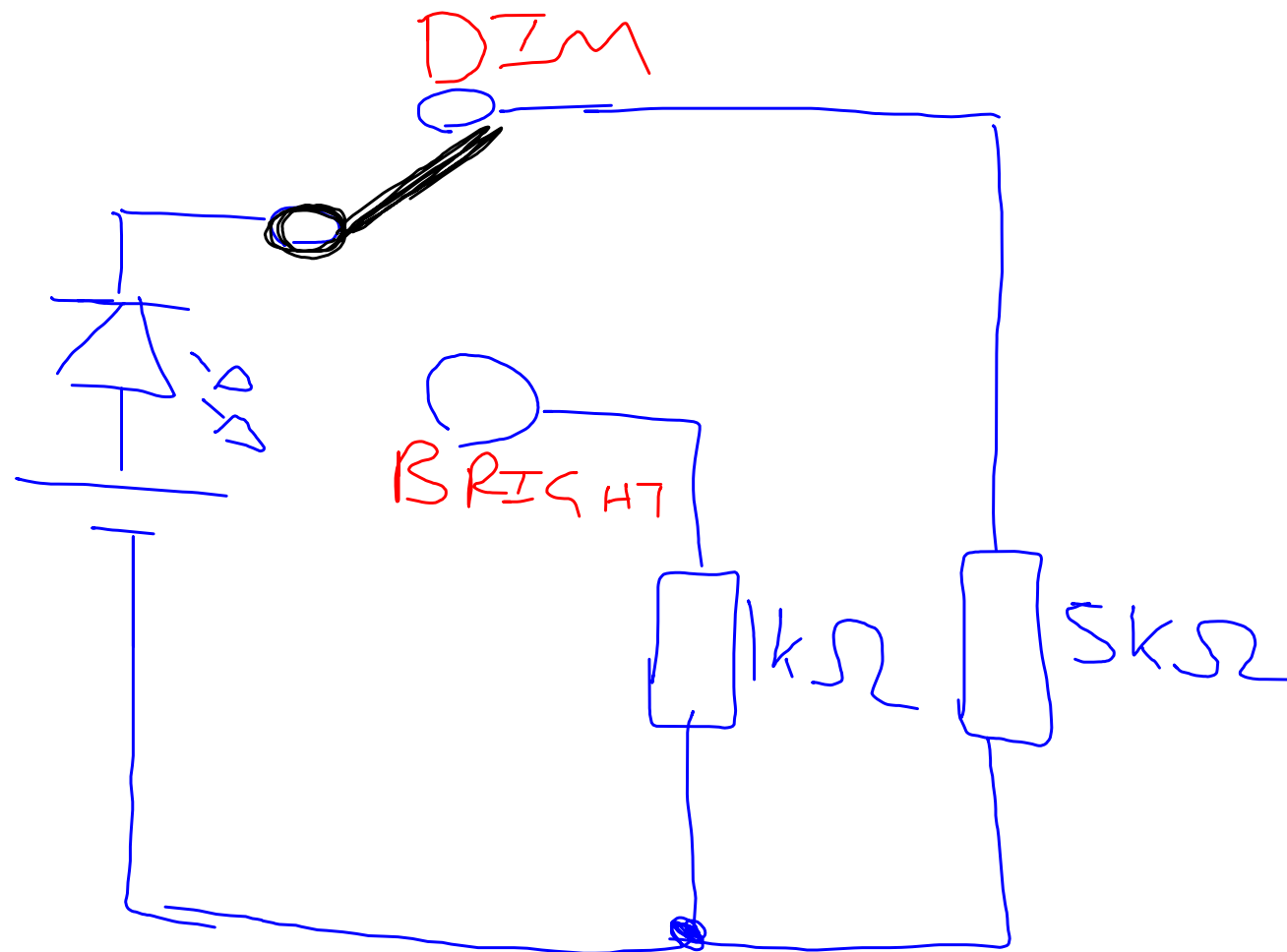
SWITCHES.

switches are electronic components that allow us to make or break circuits. There are various types of switches and have two main characteristics. the number of 'poles' (the electrical contact that can connect or disconnect circuits) and the number of 'throws' (the number of different positions we can put the pole in.)

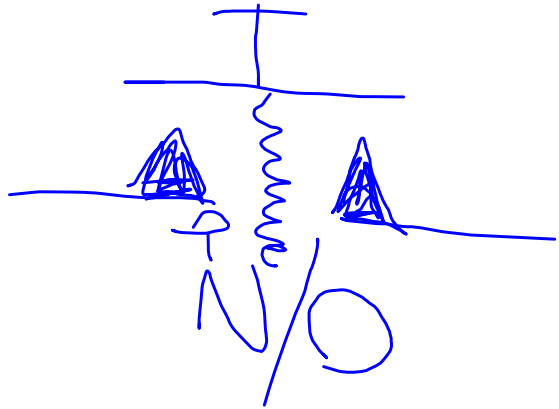


the single pole single throw switch has one pole (the black bit) this can either connect the right side of the circuit to the left, or it can disconnect it. A throw refers to the number of different contacts the pole can go to. In other words, the number of different places we can connect the left side of the circuit to.

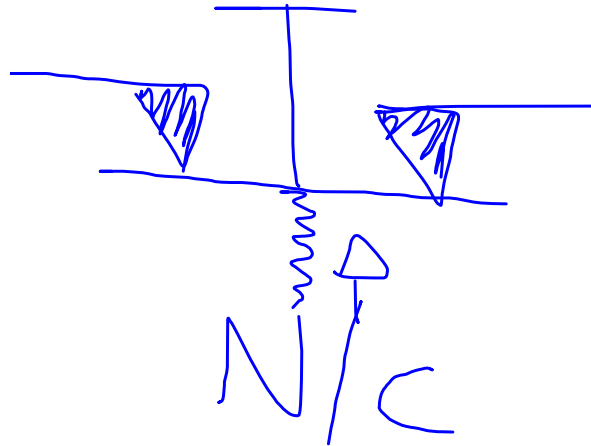
SPDT



SPST NO/NC



PBNO

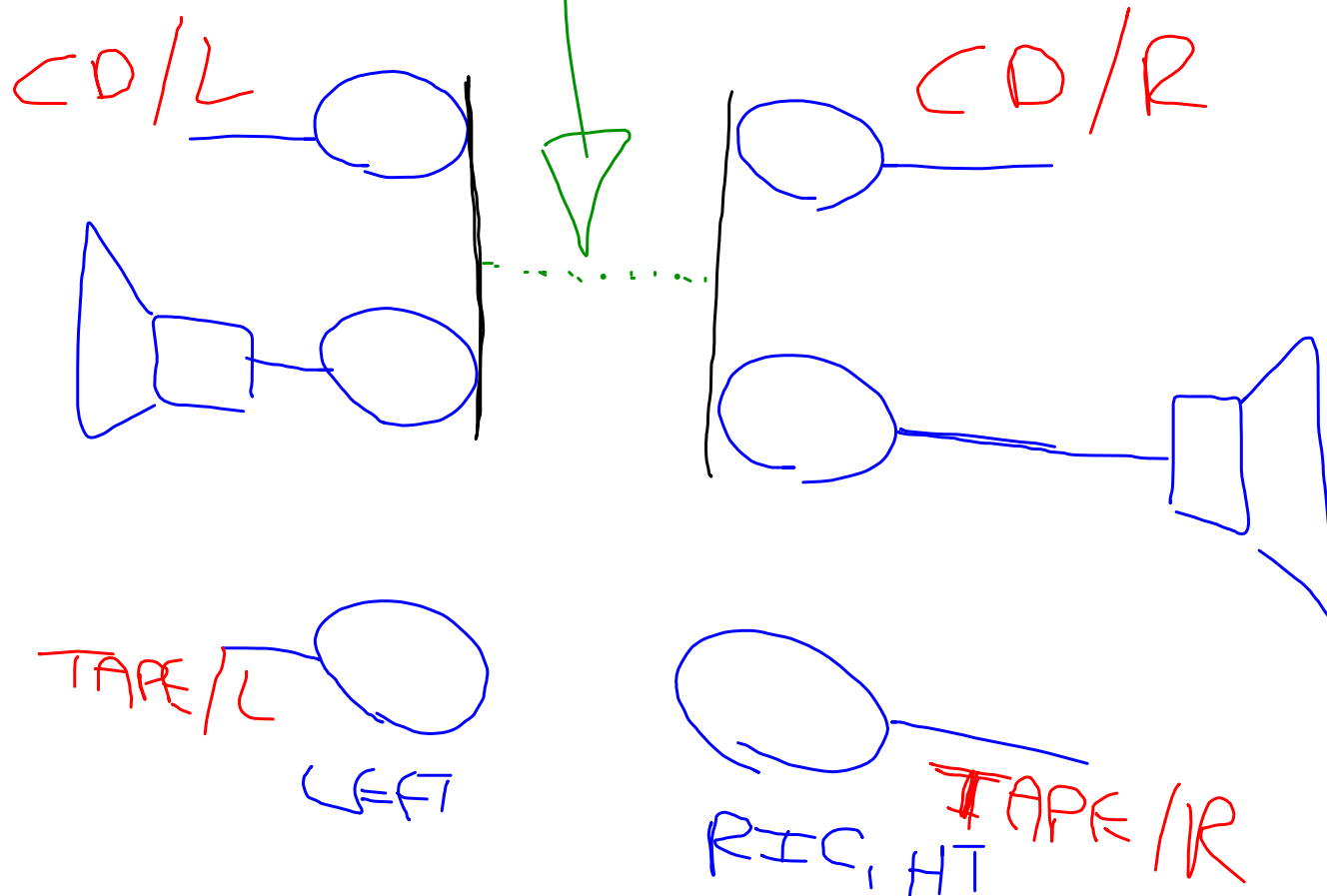


PBNC

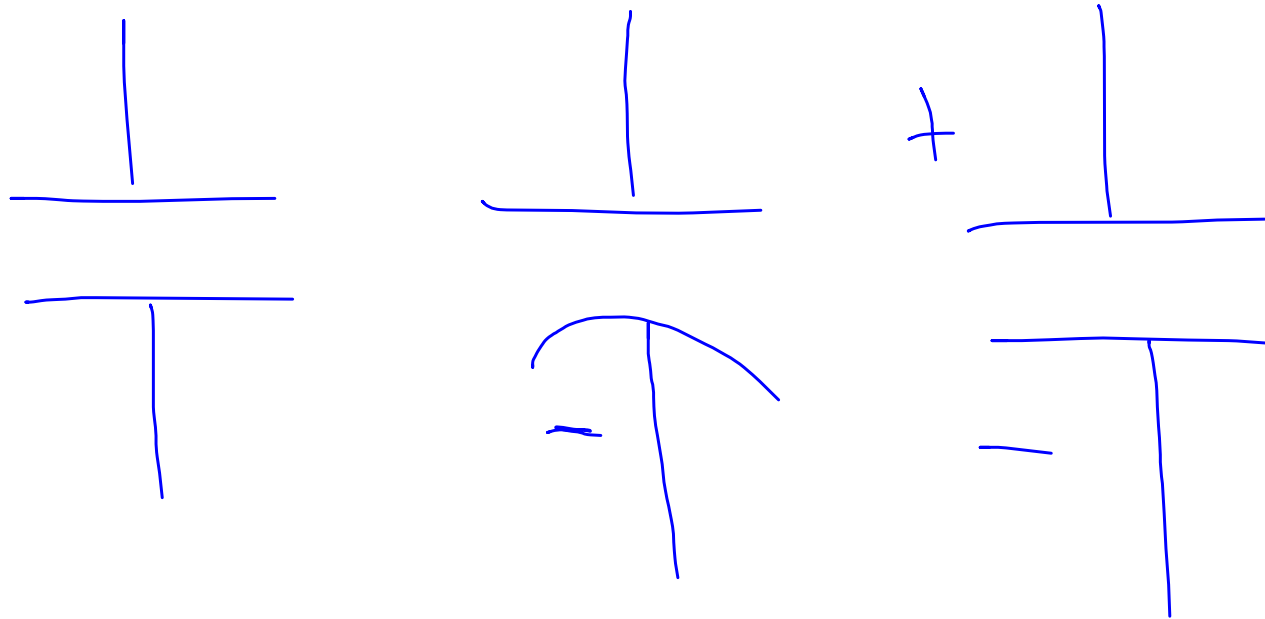
PUSH BUTTONS.

DPDT

MECHANICAL LINK
NO ELECTRICAL LINK

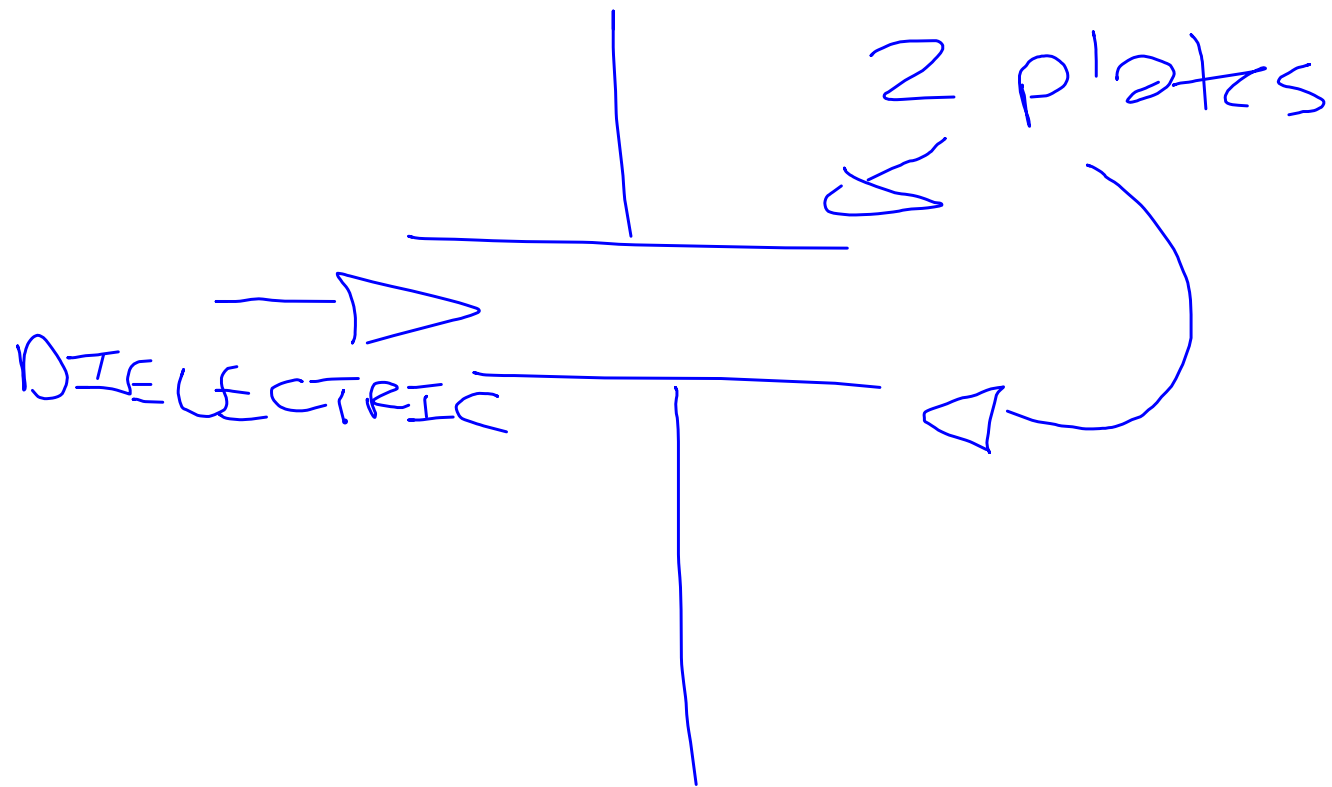


CAPACITORS.



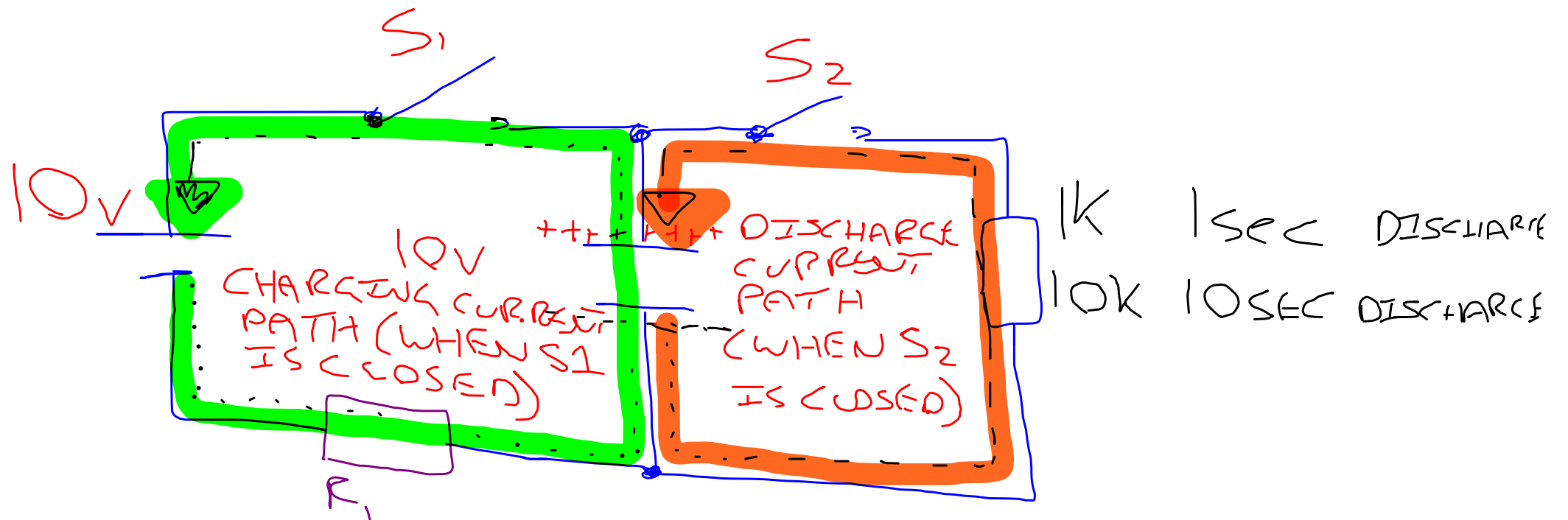
A capacitor is a device that has two conductive plates, separated by a dielectric. The dielectric can be made out of just about anything that will insulate the two plates.

Some capacitors are polarised which means that you now have a negative connection and a positive connection. You need to make sure that you connect this type of capacitor correctly when making a circuit.



Capacitors are made of two conductive plates, separated by some sort of insulator (which is given the name - dielectric)

No current flows within (or through) a capacitor, but rather, electrons can flow onto one plate and then away from the other plate.



R_1 will limit the charging current for capacitor C_1 , while R_2 will limit the discharge current.

To charge the capacitor we need to close S_1 . once charged, we can open S_1 . The capacitor will stay charged (because it does not have a discharge path).

We can then close S_2 , this will provide a discharge path for C_1 and current will flow through R_2 until the capacitor is completely discharged.

TIME CONSTANTS.

time in
seconds.

$$\rightarrow t = R \times C$$

$\nearrow$
RESISTANCE
IN
OHMS.

$\nearrow$
CAPACITANCE
IN
FARADS.

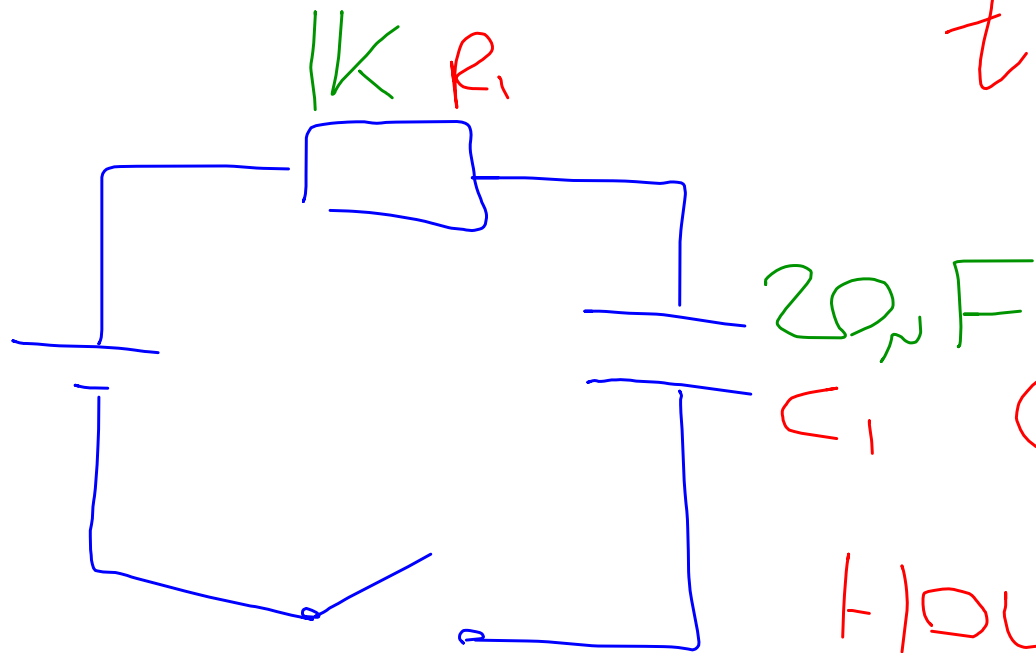
It takes a capacitor 5 time constants to fully charge or fully discharge.

RULE

a small capacitor with a low value of resistor in series with it, will charge much quicker than a large capacitor with a high value of resistor connected in series with it.

A capacitor is said to be fully charged (from being fully discharged) after 5 time constants.

TIME CONSTANTS.



$$t = R \times C$$
$$= 1k \times 20\mu F$$

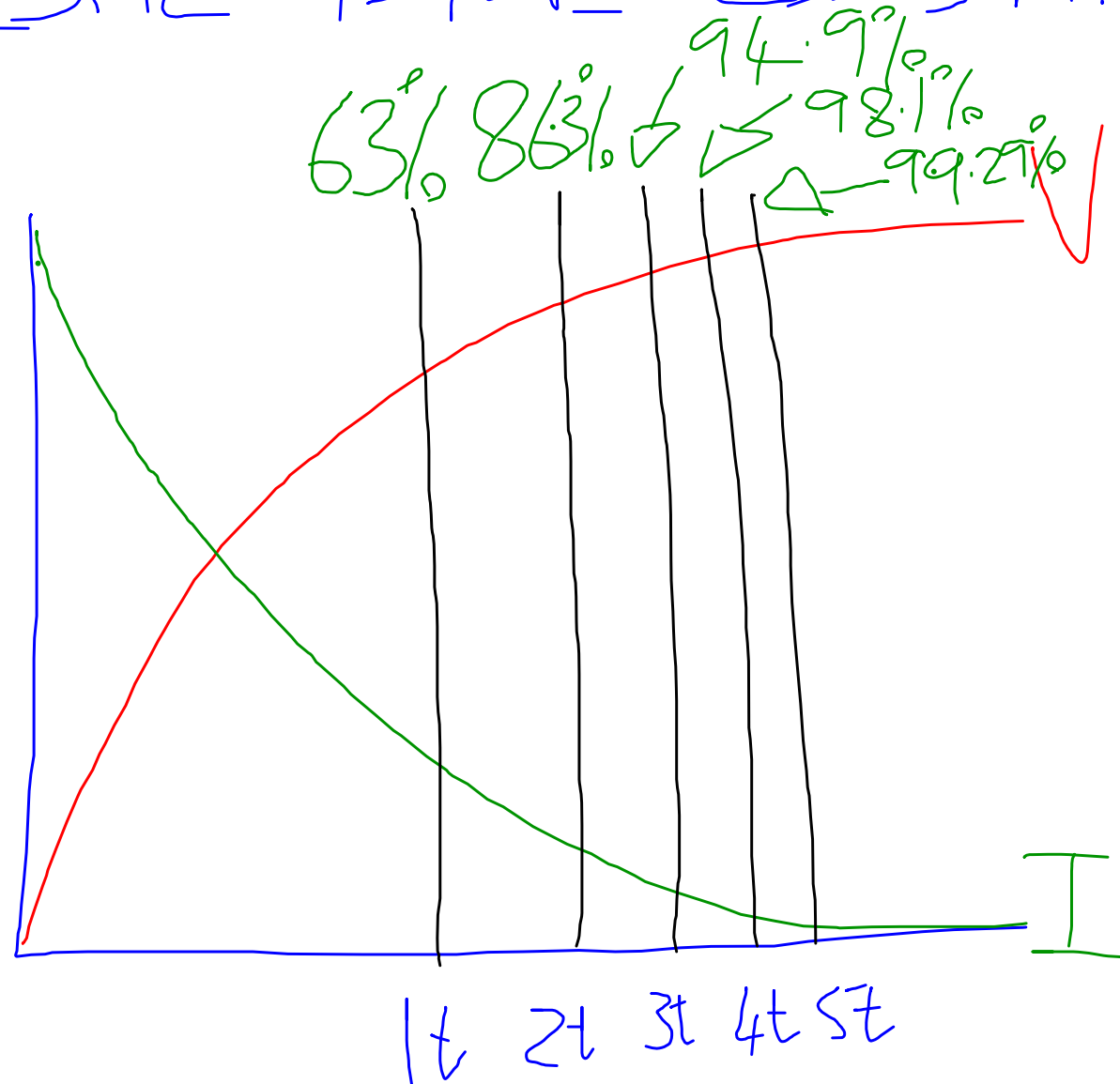
$$= 20ms$$

HOW LONG TO
FULLY CHARGE?

$$5 \times 20ms = 100ms$$

This capacitor will charge up to whatever the input power supply voltage is after 5 time constants.

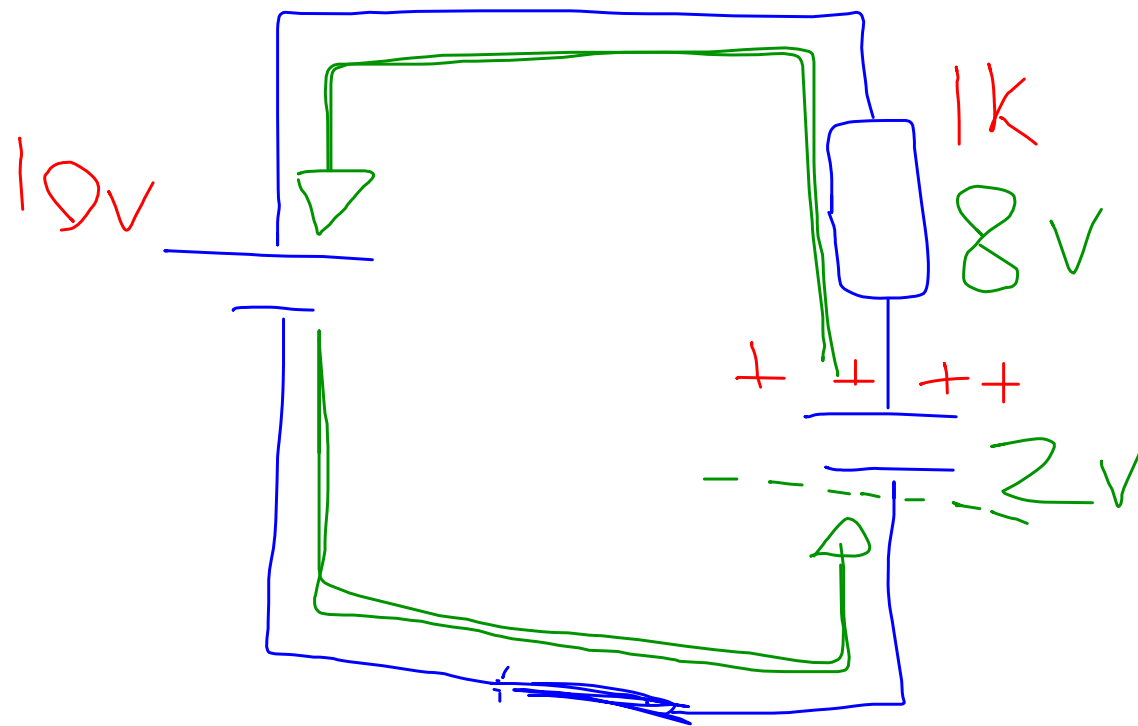
UNIVERSAL TIME CONSTANT CHART.



The universal time constant chart shows us circuit current and voltage across a capacitor as the capacitor is charging. The circuit current decreases as the capacitor is charging because as the capacitor charges, it gets more voltage. As it gets more voltage, it is taking away from the series resistor and since we work out current flow by the voltage across a resistor divided by its resistance, our current flow goes down.

This causes the capacitor to charge more slowly, but the more it charges, the more voltage the capacitor gets, therefore the less the resistor gets and so the current continues to decrease. once the capacitor is fully charged - it now has all the voltage across it, therefore leaving 0V for the resistor which means circuit current is now 0V.

WHY DOES THE CAPACITOR
CHARGE SLOWER AS TIME GOES BY?



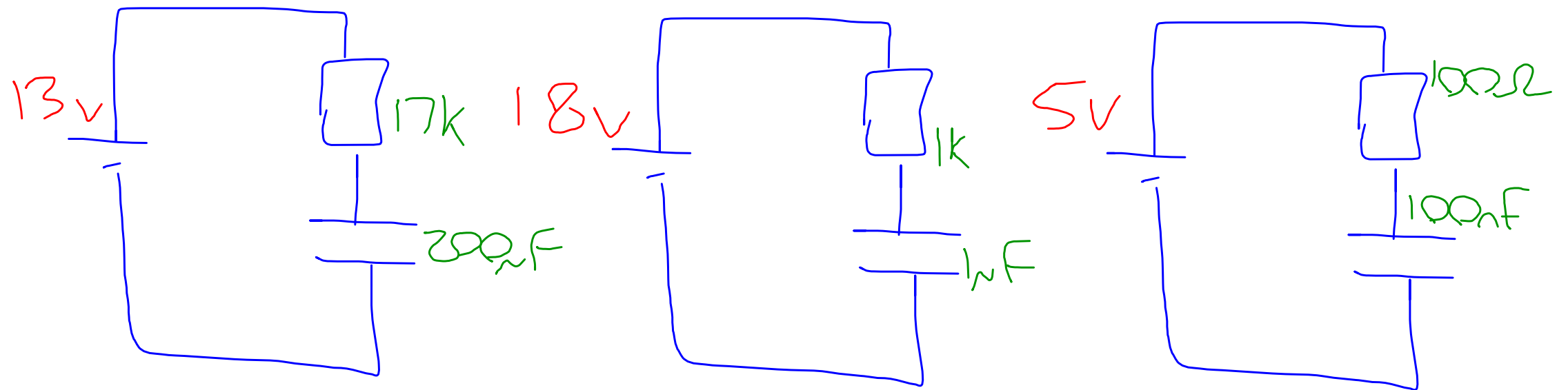
$$\frac{10V}{1k} = 10mA$$

$$\frac{9V}{1k} = 9mA$$

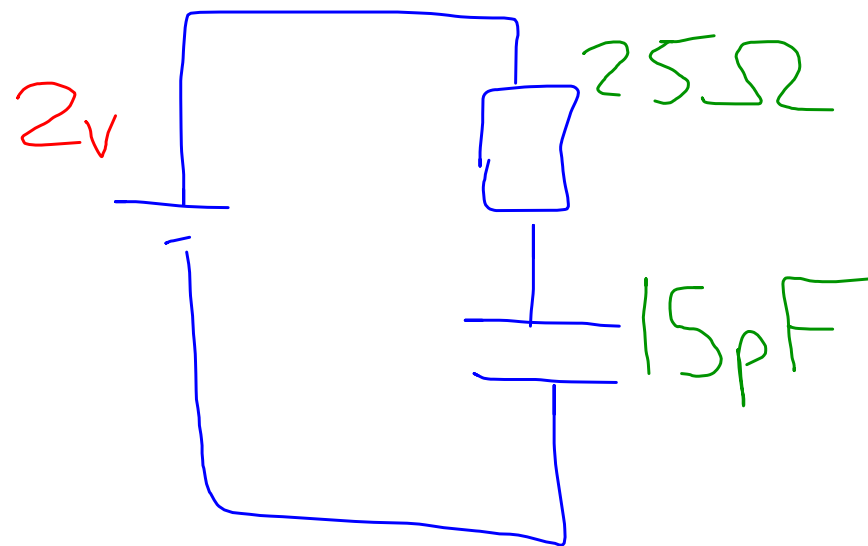
$$\frac{8V}{1k} = 8mA$$

Notice how as the capacitor charges, it gets more voltage, taking away from the resistor voltage therefore reducing the circuit current which therefore slows down the rate at which the capacitor charges.

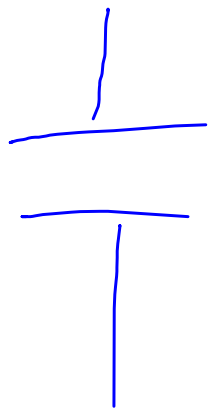
CALCULATE THE TIME CONSTANTS:



HOW LONG
WILL IT TAKE
FOR EACH TO
CHARGE?

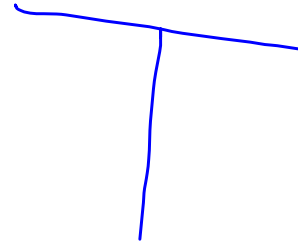


FACTORS EFFECTING CAPACITANCE



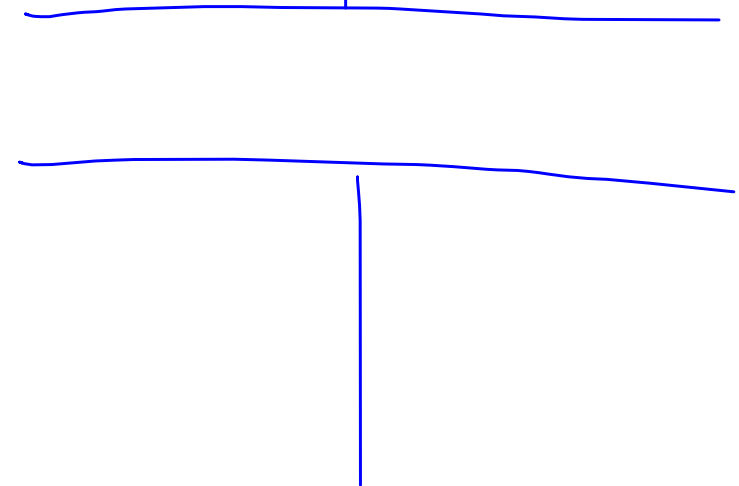
the greater the distance between plates means a lower value of capacitance

just like magnets, as we move the plates further away, the attractive force between the two plates decreases. Therefore the capacitance decreases.



the greater the area of the plates, the greater the capacitance.

This is because we can hold more electrons on one plate and more holes on the other.



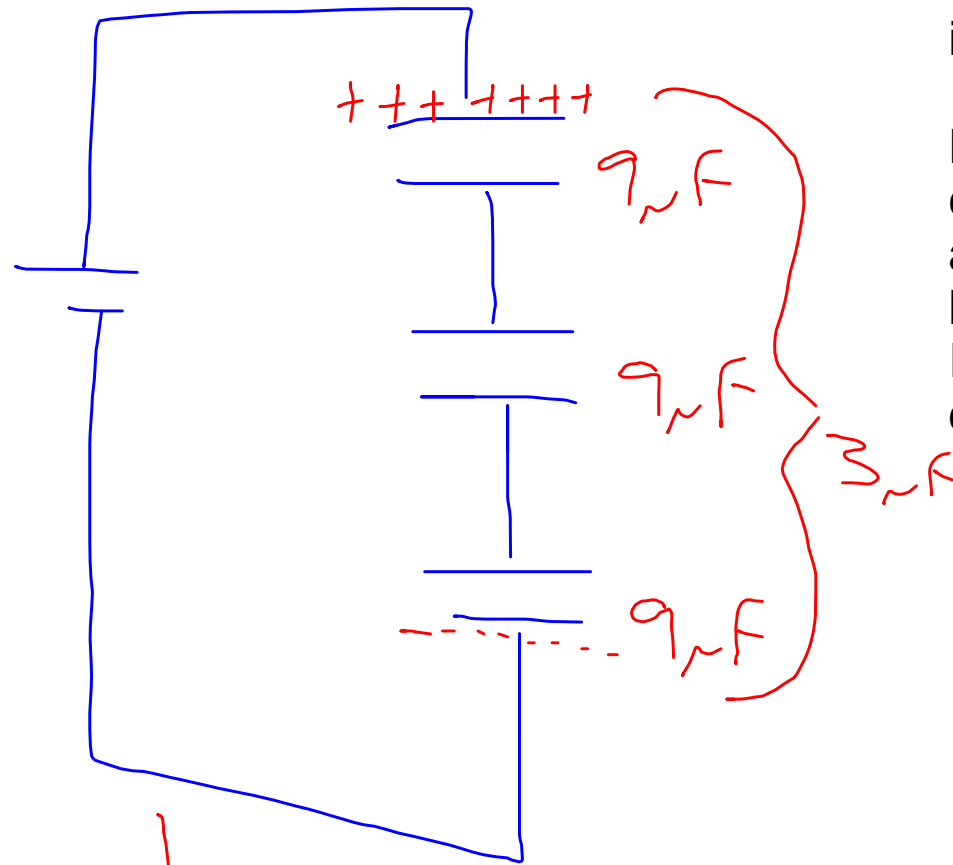
The di-electric constant (I.E. the stuff we put in between the two plates) also will have an effect on the value of capacitance.

E.G. we could use paper, bees wax, air etc...

CAPACITORS IN SERIES.

When you add capacitors in series it actually reduces the overall capacitance. This is because you are effectively increasing the distance between plates.

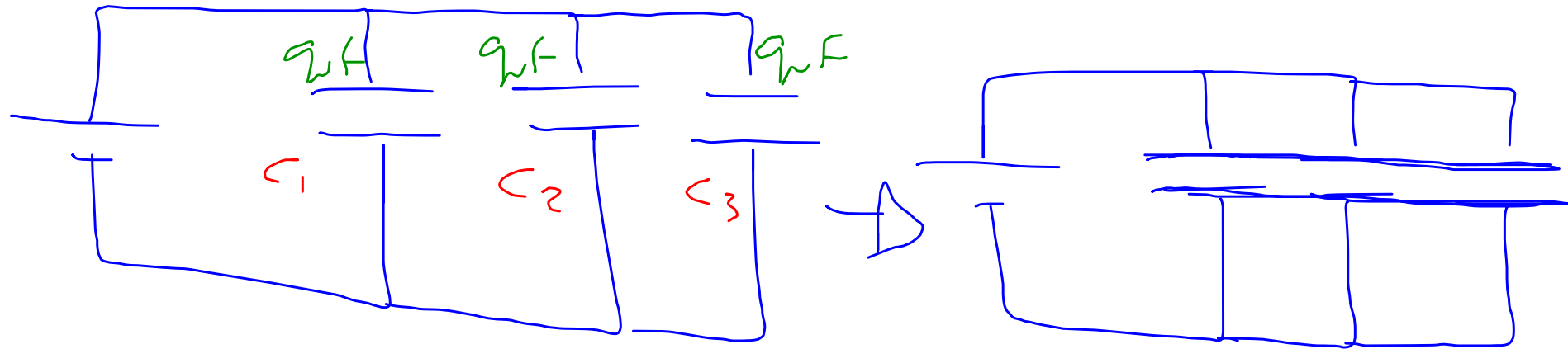
Remember there is no current flowing in / through a capacitor. It works on electrons building up on one plate and being removed from the other. The capacitor then has an electro static 'attraction between these two plates. If the plates are moved further apart, the attraction decreases.



$$C_T = \frac{1}{\frac{1}{C_1} + \frac{1}{C_2} + \frac{1}{C_3}}$$
$$= 3 \mu F$$

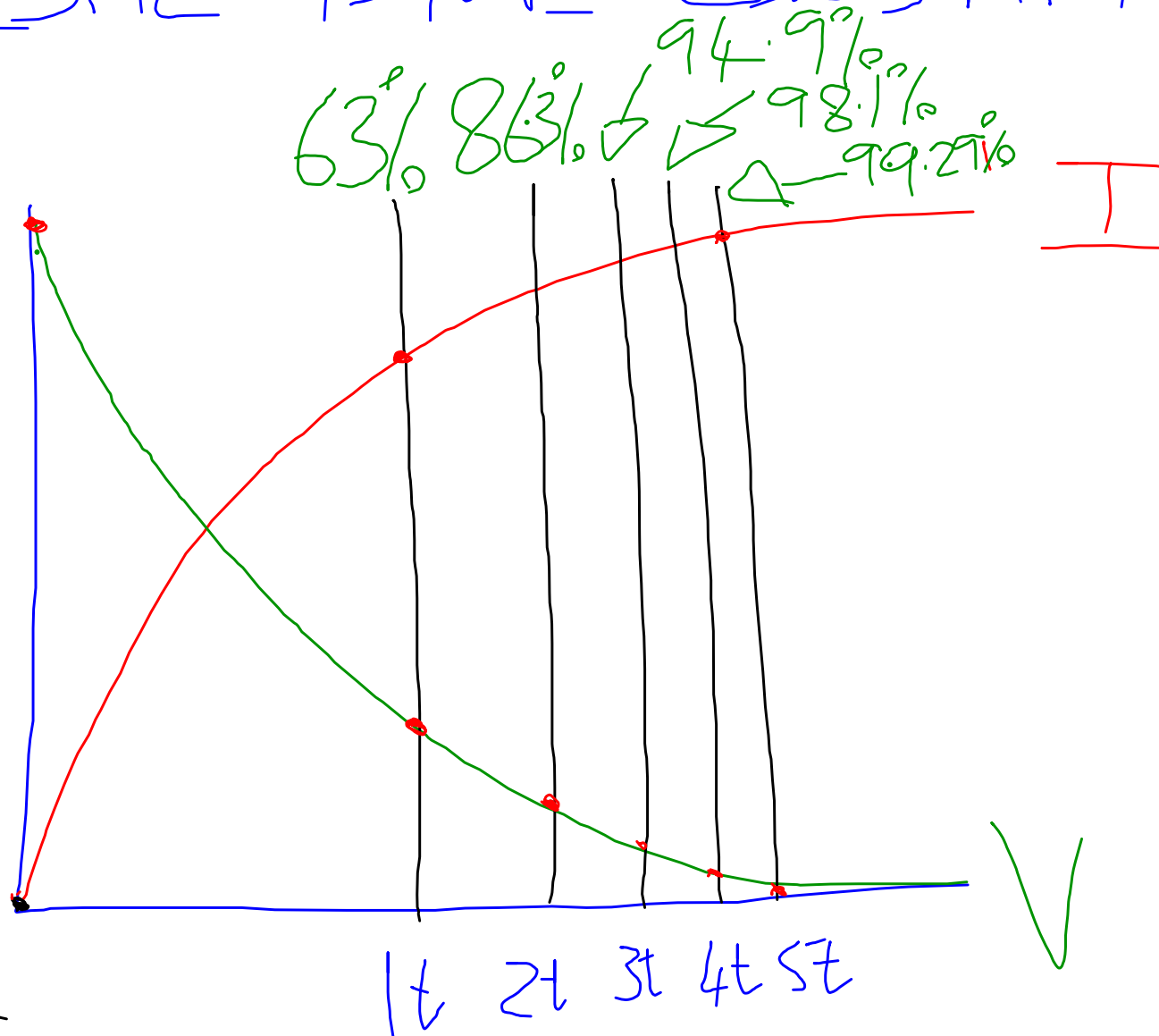
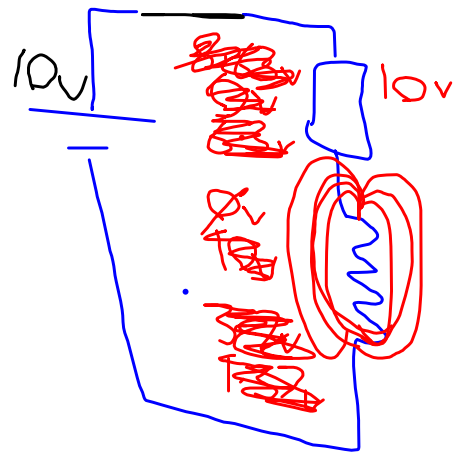
CAPACITORS IN PARALLEL.

capacitors in parallel will actually increase the overall capacitance. This is because we are effectively increasing the size (area) of the plates.



$$C_T = C_1 + C_2 + C_3$$
$$= 27\mu F$$

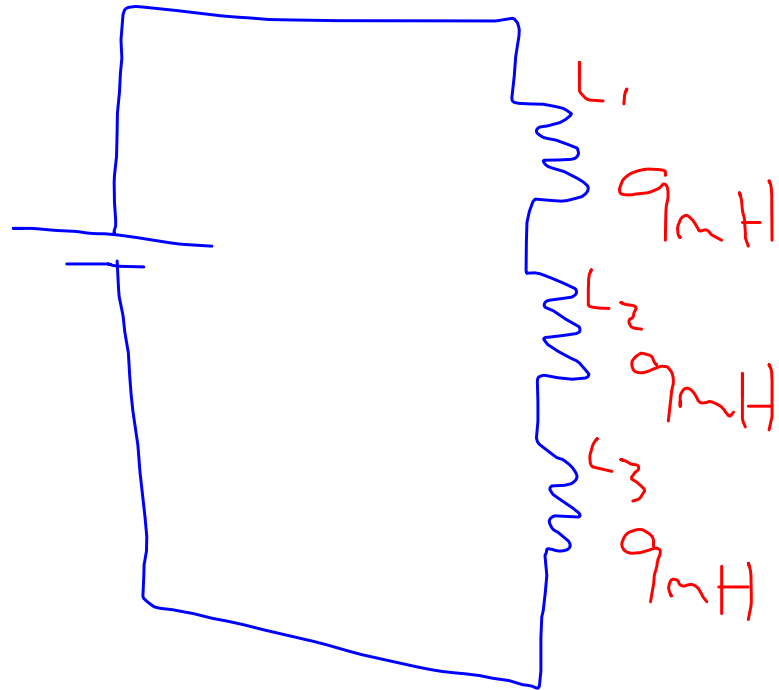
UNIVERSAL TIME CONSTANT CHART.



INDUCTOR
OPPOSES
A CHANGE
IN CURRENT.

An inductor effectively is the opposite to a capacitor. An inductor opposes any change in the circuit current. When we first turn power on to this circuit, we have a huge change I.E. 0V to 10V. The inductor doesn't like this so he grabs all the voltage (due to his magnetic field moving very fast and generating an EMF into it's own coils) this leaves 0V for the resistor and therefor no circuit current. Eventually the magentic field approaches it's maximum strength and no longer moves anymore. Since it stops moving, it stops cutting into it's own coils, therefor it stops inducing a voltage into itself and then the series resistor gets all the voltage. So after 5 time constants, the opposite has happened comapered to a capacitor. Current will be maximum and the voltage across the inductor is minimum.

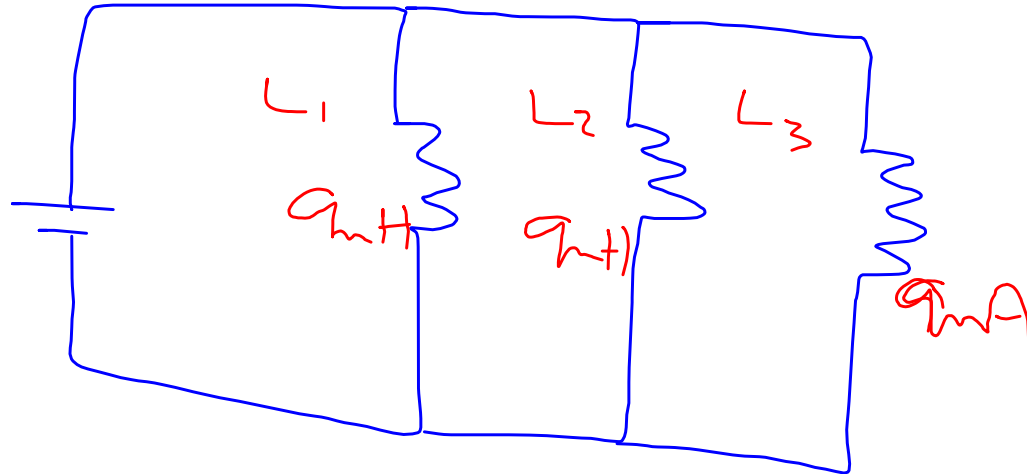
INDUCTORS IN SERIES.



inductors in series are just like resistors in series. We just add them together.

$$L_T = L_1 + L_2 + L_3$$
$$= 27\text{mH}$$

INDUCTORS IN PARALLEL.

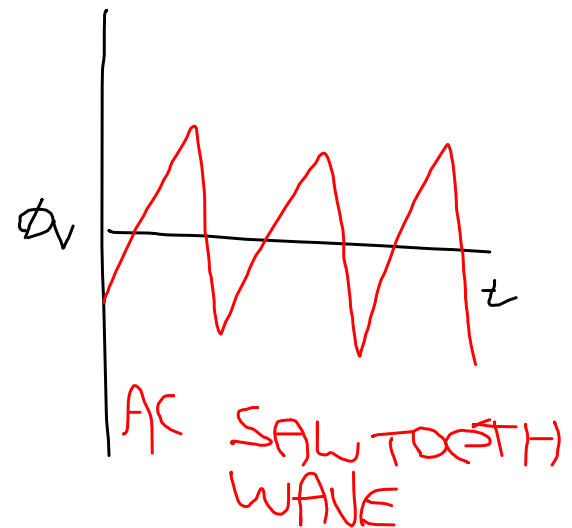
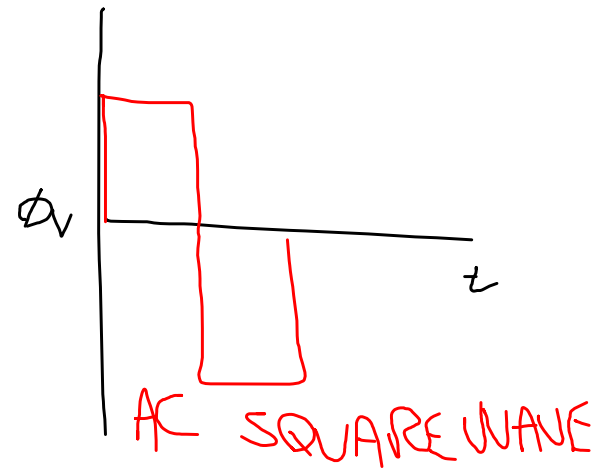
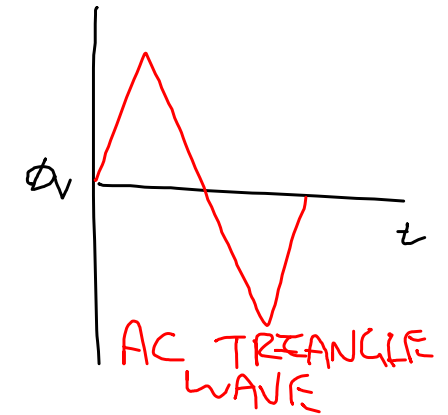
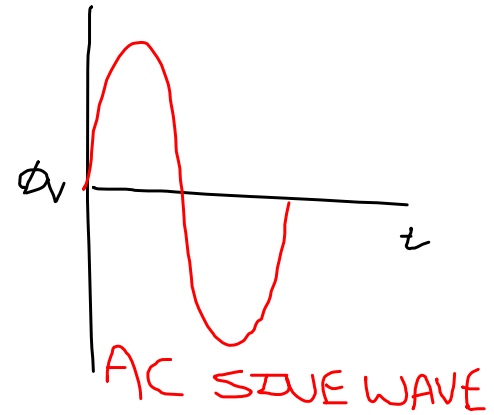
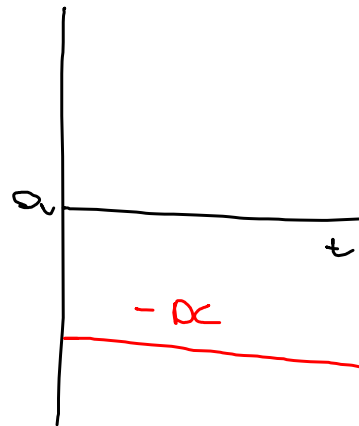
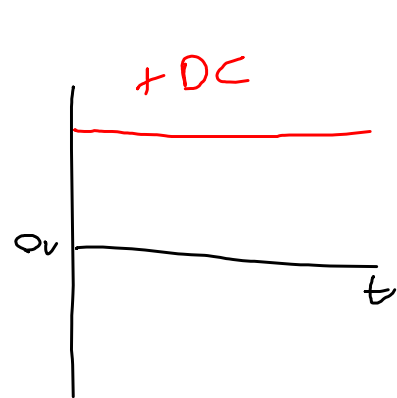


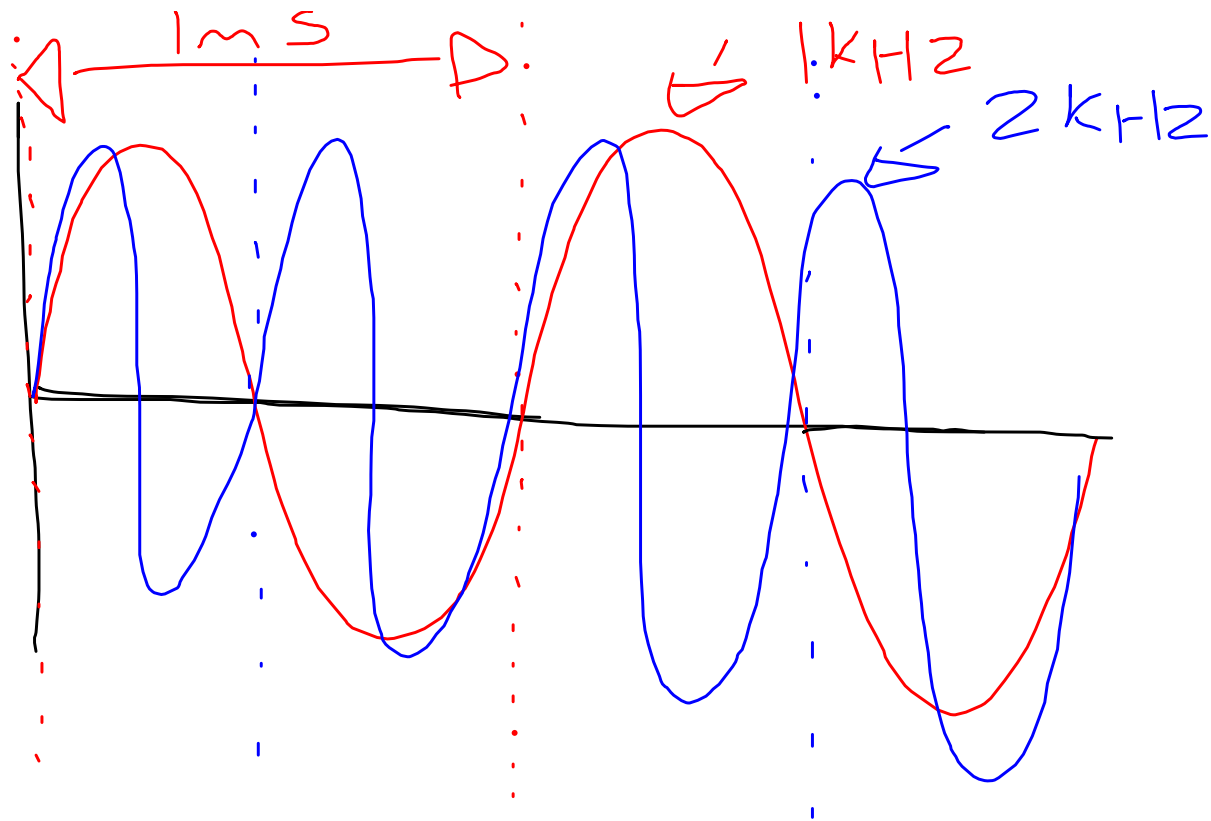
inductors in parallel are just like resistors in parallel. We use the reciprocal method. or if you want, you can use the product over sum method if there are only two inductors.

$$L_T = \frac{1}{\frac{1}{L_1} + \frac{1}{L_2} + \frac{1}{L_3}}$$

$$= 3mH$$

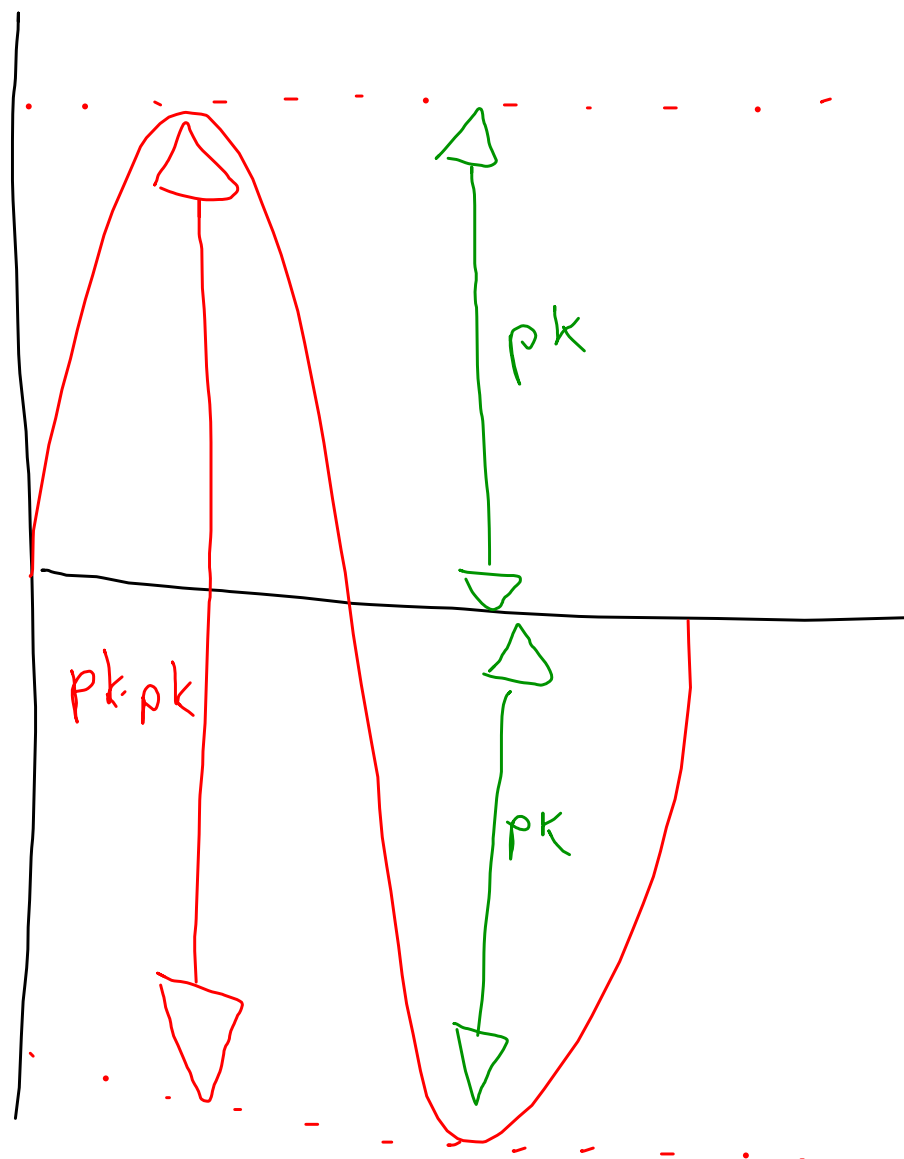
DIFFERENT SIGNALS.





BLUE IS TWICE THE FREQUENCY
OF RED $\therefore$ IT TAKES $\frac{1}{2}$ AS LONG
TO DRAW EACH SINE WAVE $\therefore$
WE CAN GET TWICE AS MANY IN
THE SAME AMOUNT OF TIME.

VOLTAGE MEASUREMENTS.



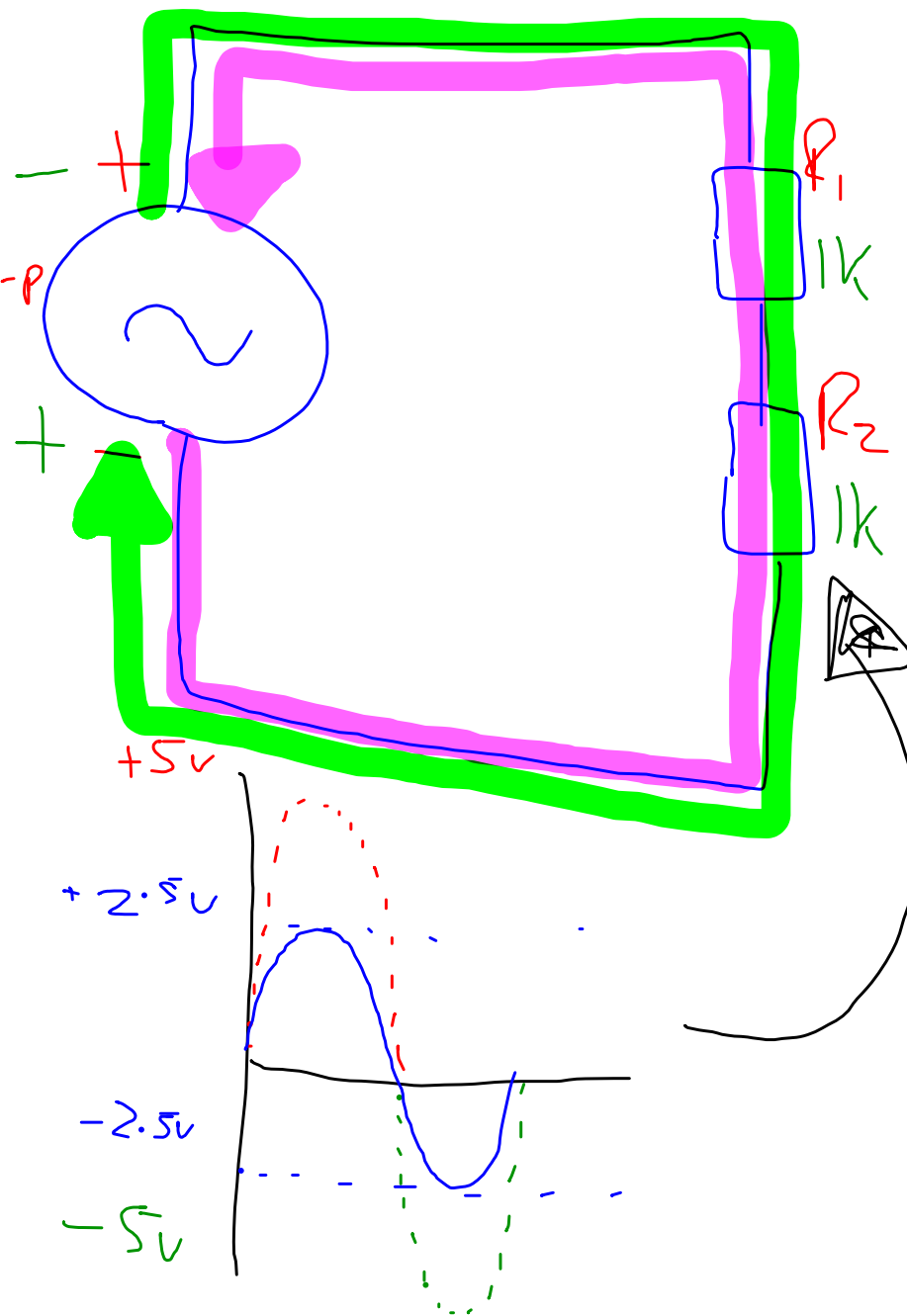
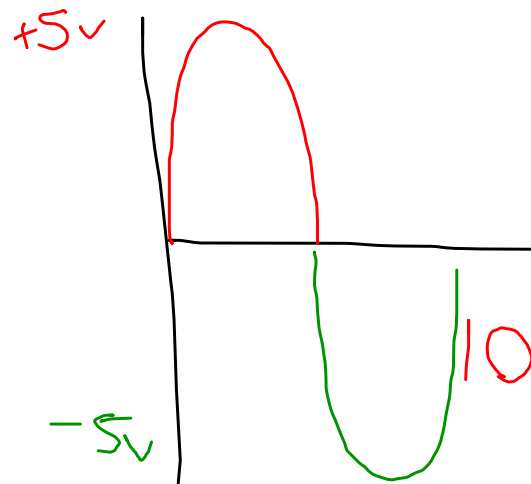
$$1 \text{ } V_{p-p}$$

$$5 V_p \left(\frac{1}{2} p-p \right)$$

$$3.5 V_{rms} (0.707 \times V_p)$$

$$3.19 V_{AV} (0.637 \times V_p)$$

AC RESISTIVE CIRCUITS.



$$R_T = 2k$$

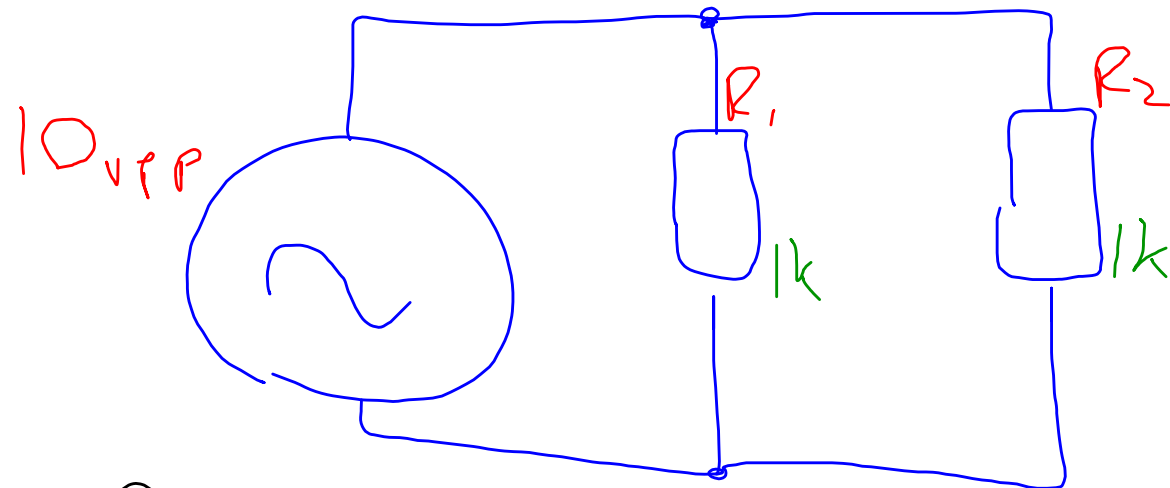
$$I_{T\text{p-p}} = \frac{10V_{p-p}}{2k} = 5mA_{p-p}$$

$$V_{R1} = 5mA_{p-p} \times 1k = 5V_{p-p}$$

$$V_{R2} = 5mA_{p-p} \times 1k = 5V_{p-p}$$

voltage and current are in phase

PARALLEL.



$$R_T = 500\Omega$$

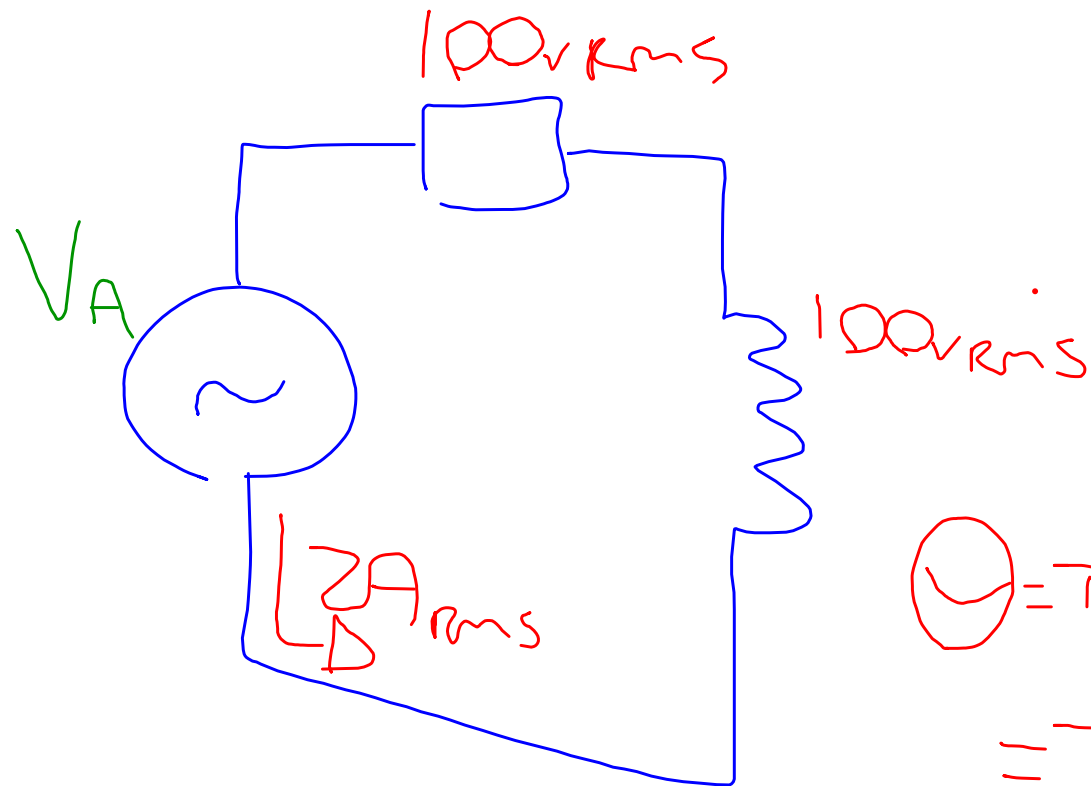
$$I_{T_{PP}} = \frac{10_{VPP}}{500\Omega} = 20mA_{PP}$$

$$V_{R1} = 10_{VPP}$$
$$V_{R2} = 10_{VPP}$$

$$I_{R1} = \frac{10_{VPP}}{1k} = 10mA_{PP}$$

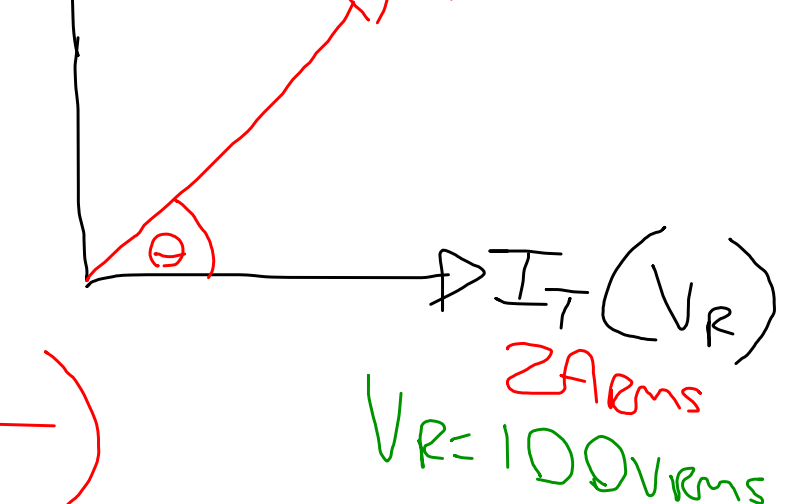
$$I_{R2} = \frac{10_{VPP}}{1k} = 10mA_{PP}$$

voltage and current are in phase



CIVIL

$V_L 100V_{rms} (V_A)$
 $141.4V_{rms}$



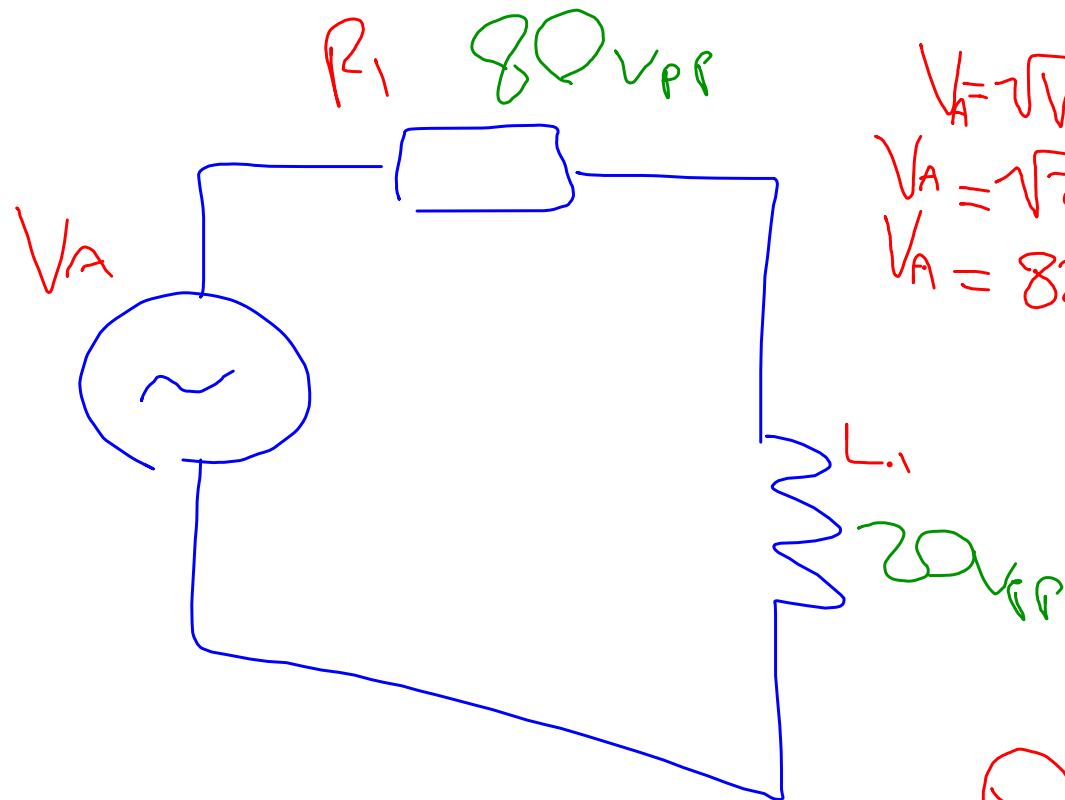
$$\begin{aligned}\theta &= \tan^{-1} \left(\frac{V_L}{V_R} \right) \\ &= \tan^{-1} \left(\frac{100V_{rms}}{100V_{rms}} \right) \\ &= 45^\circ\end{aligned}$$

$$\begin{aligned}V_A &= \sqrt{V_L^2 + V_R^2} \\ &= \sqrt{100^2 + 100^2} \\ &= 141.4V_{rms}\end{aligned}$$

If we want to find the voltage applied when we have a reactive component in the circuit, we cannot just add the two voltage drops together. This is because the voltage across the inductor will be out of phase (by 90 degrees) to the voltage across the resistor. Therefore, we need to add them together vectorially.

In this example, the applied voltage must be 141.4Vrms and it will be leading the circuit current by 45 degrees.

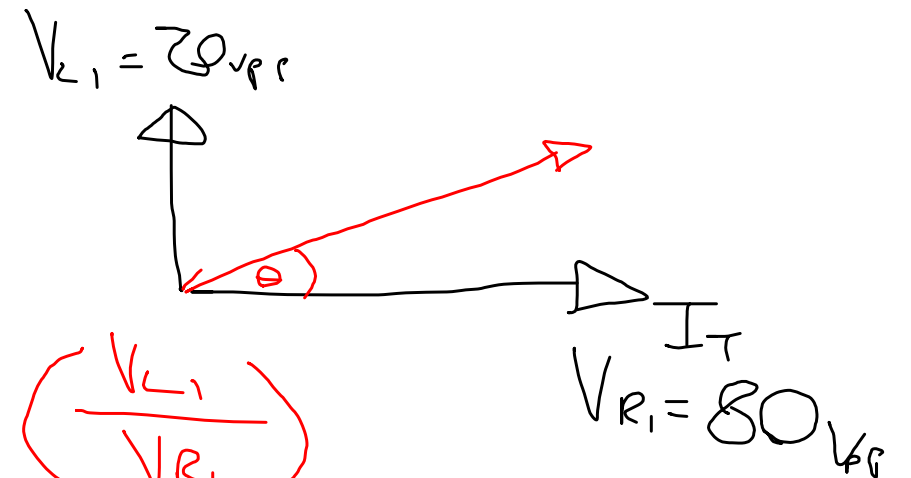
CIVIL



$$V_A = \sqrt{V_L^2 + V_R^2}$$

$$V_A = \sqrt{20_{PP}^2 + 80_{PP}^2}$$

$$V_A = 82.46V_{PP}$$



$$\theta = \tan^{-1} \left(\frac{V_{L_1}}{V_{R_1}} \right)$$

$$= \tan^{-1} \left(\frac{20_{PP}}{80_{PP}} \right)$$

$$= 14.04^\circ$$



$C I$ $V I L$

$$X_{L1} = 2\pi \cdot 7\text{kHz} \cdot 45\text{mH} = 1.98\text{k}\Omega$$

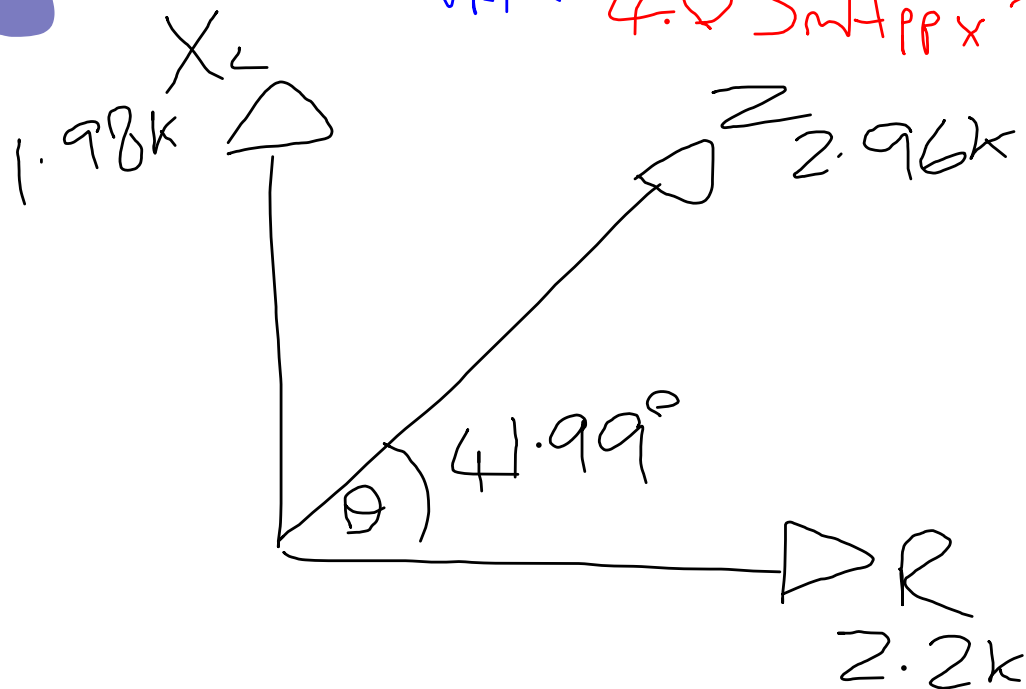
$$Z = \sqrt{2.2\text{k}^2 + 1.98\text{k}^2} = 2.96\text{k}\Omega$$

$$\Theta = \tan^{-1}\left(\frac{X_{L1}}{R_1}\right) = 41.99^\circ$$

$$I_{PP} = \frac{12\text{V}_{PP}}{2.96\text{k}\Omega} = 4.05\text{mA}_{PP}$$

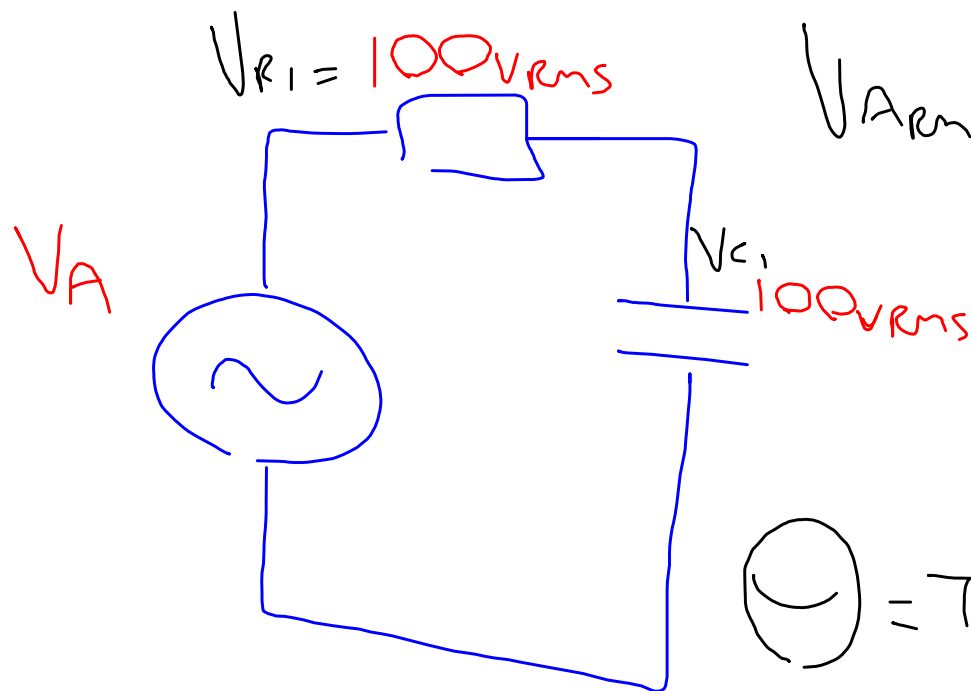
$$V_{L1} = 4.05\text{mA}_{PP} \times 1.98\text{k}\Omega = 8.02\text{V}_{PP}$$

$$V_{R1} = 4.05\text{mA}_{PP} \times 2.2\text{k}\Omega = 8.91\text{V}_{PP}$$



CAPACITOR CIRCUIT.

CIVIL



$$V_{Arms} = \sqrt{V_C^2 + V_R^2}$$

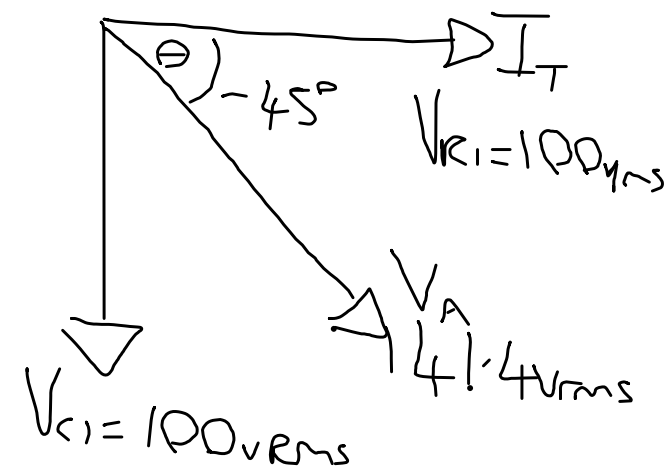
$$= \sqrt{100_{Vrms}^2 + 100_{Vrms}^2}$$

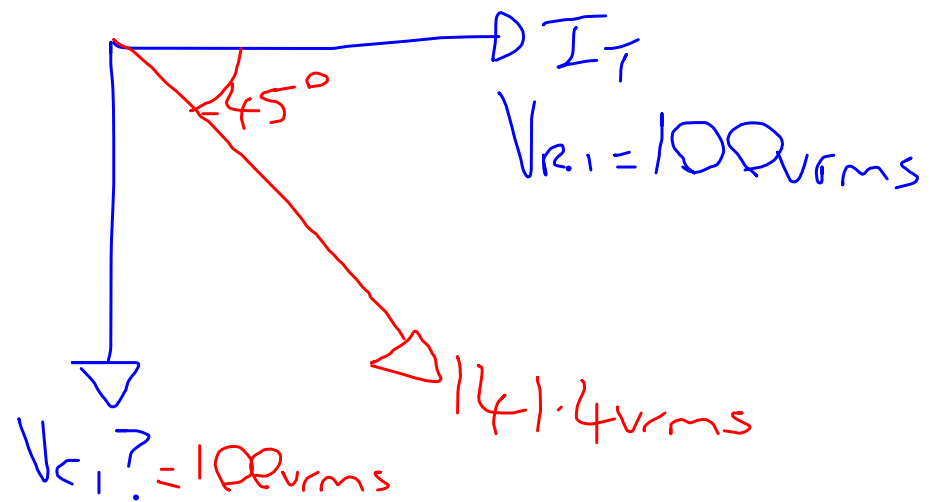
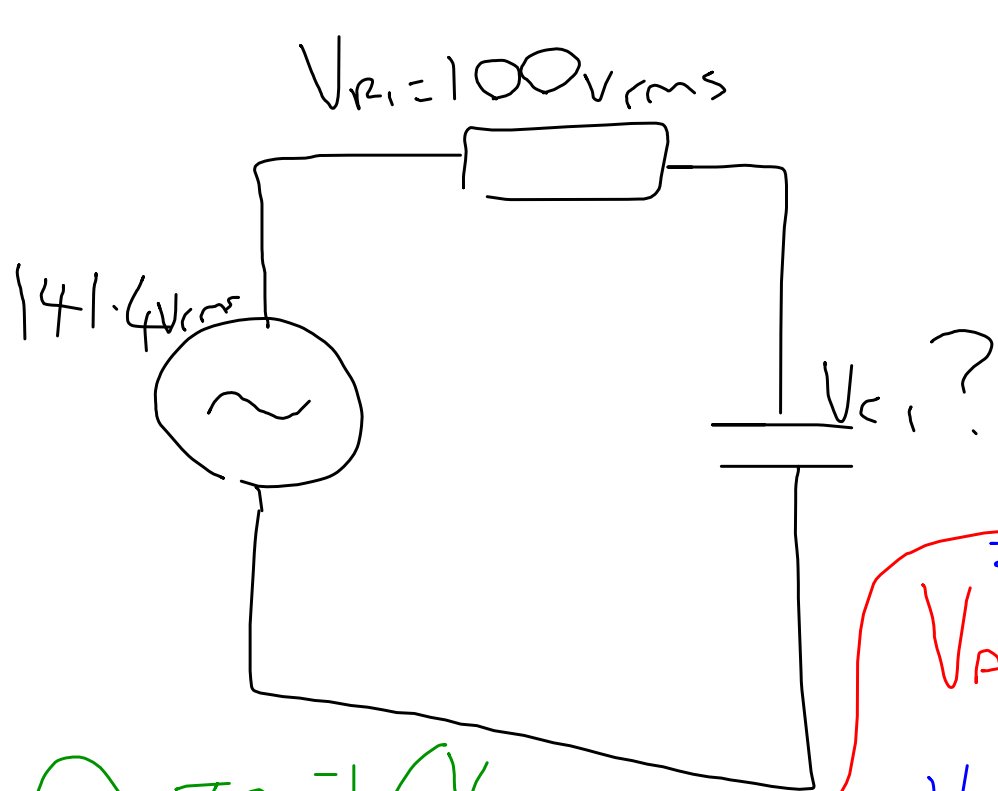
$$= 141.4 \text{ Vrms}$$

$$\theta = \tan^{-1} \left(\frac{V_C}{V_R} \right)$$

$$\theta = \tan^{-1} \left(\frac{100_{Vrms}}{100_{Vrms}} \right)$$

$$\theta = 45^\circ$$





$$\Theta = \tan^{-1} \left(\frac{V_{C1}}{V_{R1}} \right)$$

$$\tan \Theta = \frac{V_{C1}}{V_{R1}}$$

$$\tan \Theta \times V_{R1} = V_{C1}$$

$$\therefore V_{C1} = \tan \Theta \times V_{R1}$$

$$V_{C1} = \tan 45^\circ \times 100 \text{ Vrms} = 100 \text{ Vrms}$$

$$V_A^2 = V_{C1}^2 + V_{R1}^2$$

$$V_A^2 - V_{R1}^2 = V_{C1}^2 + V_{R1}^2 - V_{R1}^2$$

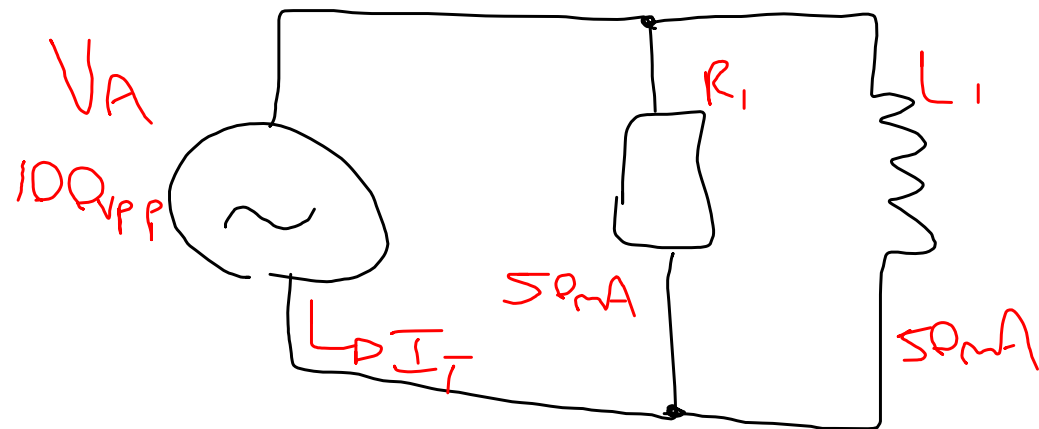
$$\sqrt{V_A^2 - V_{R1}^2} = \sqrt{V_{C1}^2}$$

$$\sqrt{V_A^2 - V_{R1}^2} = V_{C1}$$

$$\therefore V_{C1} = \sqrt{V_A^2 - V_{R1}^2}$$

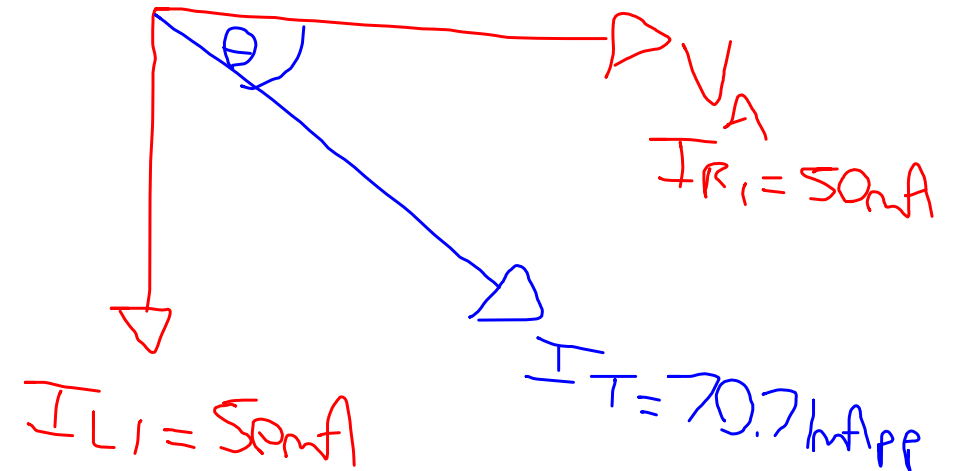
$$V_{C1} = \sqrt{141.4_{\text{Vrms}}^2 - 100_{\text{Vrms}}^2} = 100 \text{ Vrms}$$

PARALLEL RL



$$\begin{aligned}
 I_T &= \sqrt{I_{L_1}^2 + I_{R_1}^2} \\
 &= \sqrt{50mA_{pp}^2 + 50mA_{pp}^2} \\
 &= 70.7mA_{pp}
 \end{aligned}$$

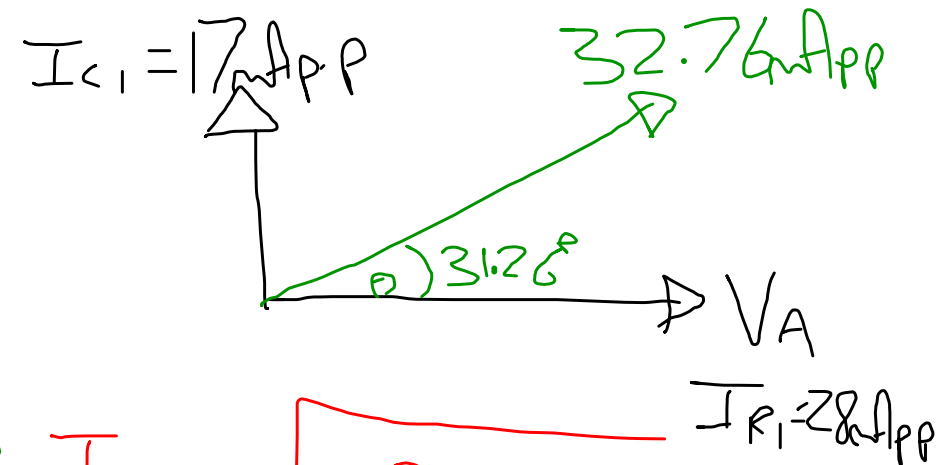
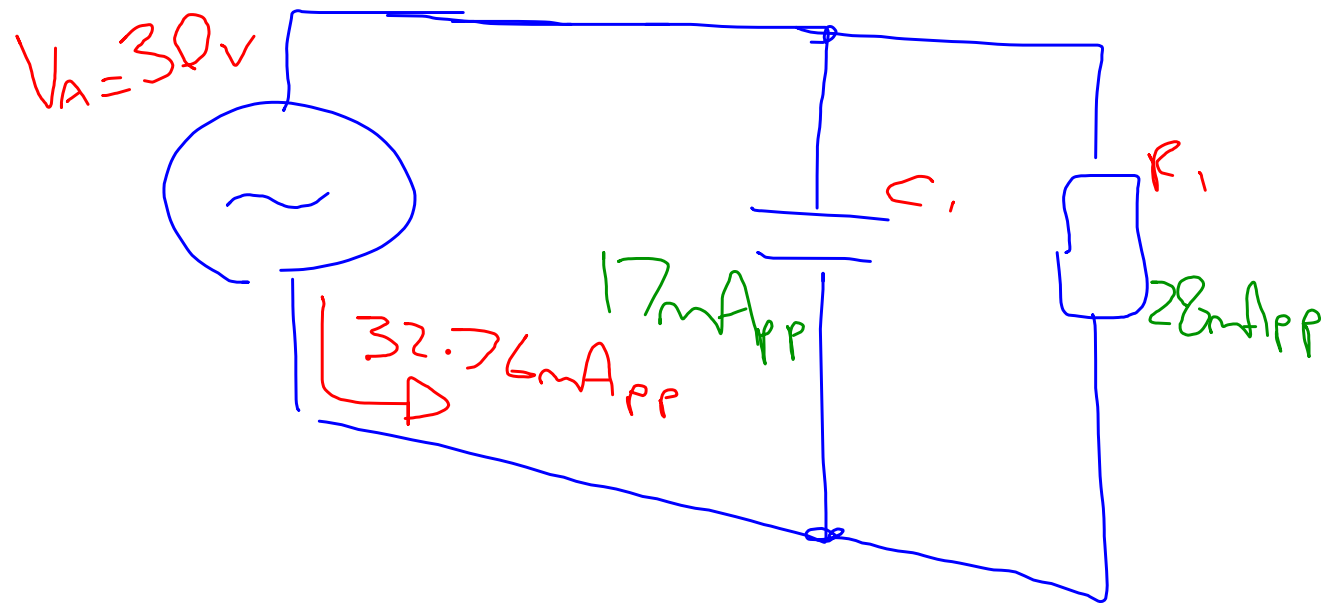
CIVIL



$$\begin{aligned}
 \theta &= \tan^{-1} \left(\frac{I_{L_1}}{I_{R_1}} \right) \\
 &= \tan^{-1} \left(\frac{50mA}{50mA} \right) \\
 &= 45^\circ
 \end{aligned}$$

PARALLEL RC

CIVIL



$$I_T = \sqrt{I_{C_1}^2 + I_{R_1}^2}$$

$$I_T = \sqrt{17mA_{pp}^2 + 28mA_{pp}^2} = 32.76mA_{pp}$$

$$\theta = \tan^{-1} \left(\frac{I_{C_1}}{I_{R_1}} \right)$$

$$= \tan^{-1} \left(\frac{17mA_{pp}}{28mA_{pp}} \right)$$

$$\theta = 31.26^\circ$$

REACTANCE. (IN OHMS Ω)

INDUCTIVE
REACTANCE

$$X_L = 2\pi f L$$

THE HIGHER
THE FREQUENCY
THE MORE IT
OPPOSES CURRENT

$$X_L = 2\pi \emptyset 22\text{mH} = \emptyset \Omega$$

$$X_L = 2\pi 100\text{Hz} 22\text{mH} = 13.82\Omega$$

$$X_L = 2\pi 10\text{kHz} 22\text{mH} = 1.38\text{k}\Omega$$

CAPACITIVE
REACTANCE

$$X_C = \frac{1}{2\pi f C}$$

$$X_C = \frac{1}{2\pi \emptyset 22\mu\text{F}} = \infty \Omega$$

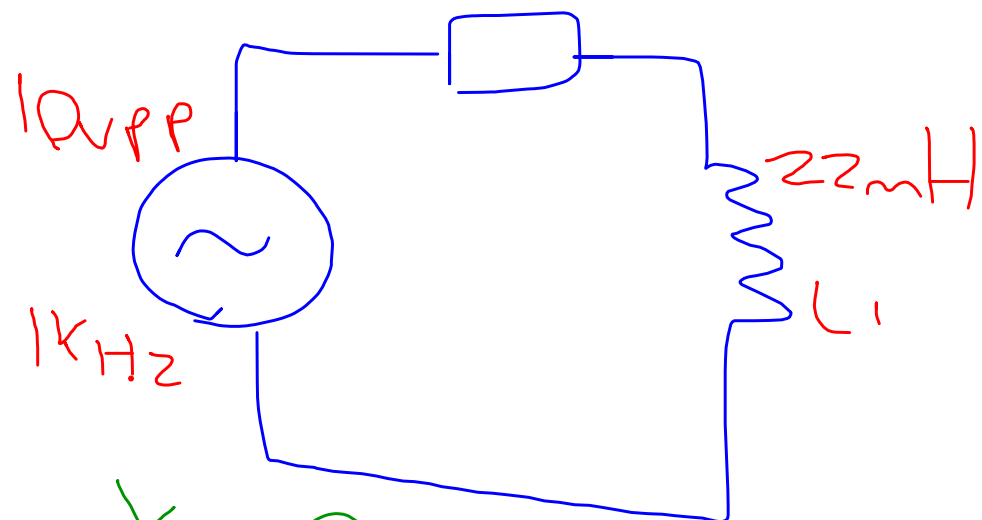
$$X_C = \frac{1}{2\pi 100\text{Hz} 22\mu\text{F}} = 72.34\Omega$$

$$X_C = \frac{1}{2\pi 10\text{kHz} 22\mu\text{F}} = 723\text{m}\Omega$$

THE HIGHER
THE FREQUENCY
THE MORE IT
ALLOWS CURRENT
TO FLOW

WHAT IS THE

R_1 100Ω



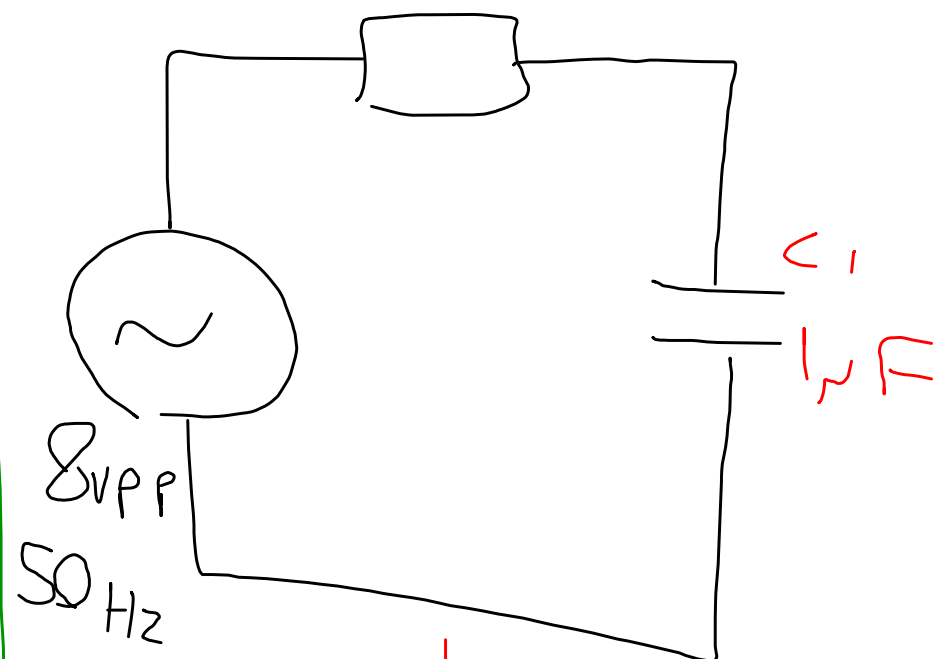
$$X_L = 2\pi fL$$

$$X_L = 2\pi 1kHz 22mH$$

$$X_L = 138.23\Omega$$

REACTANCE?

R_1 750Ω

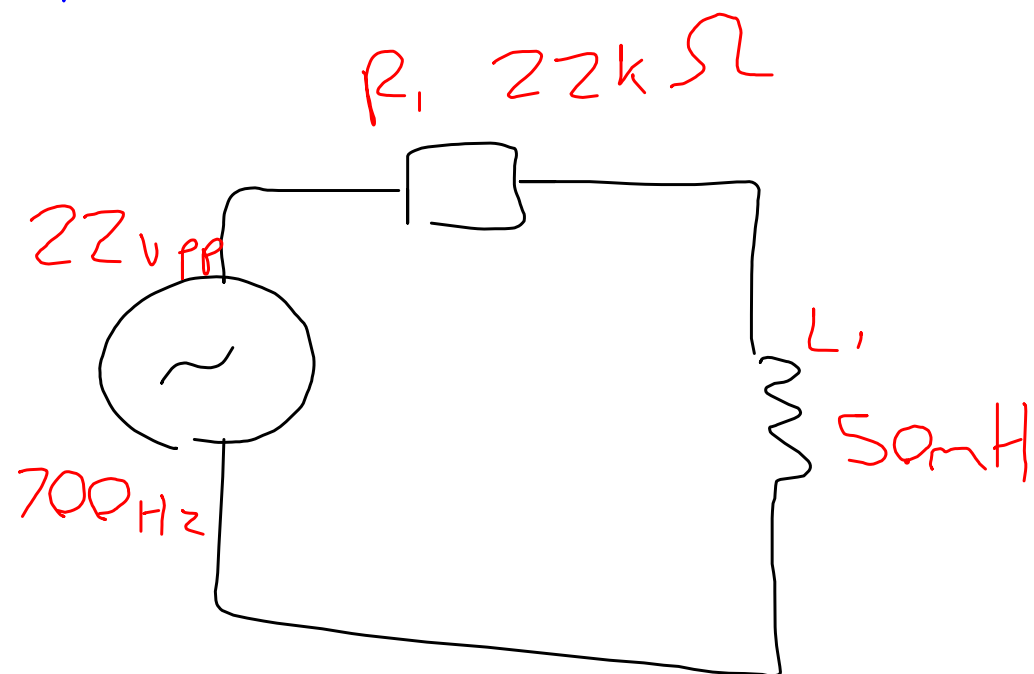


$$X_C = \frac{1}{2\pi fC}$$

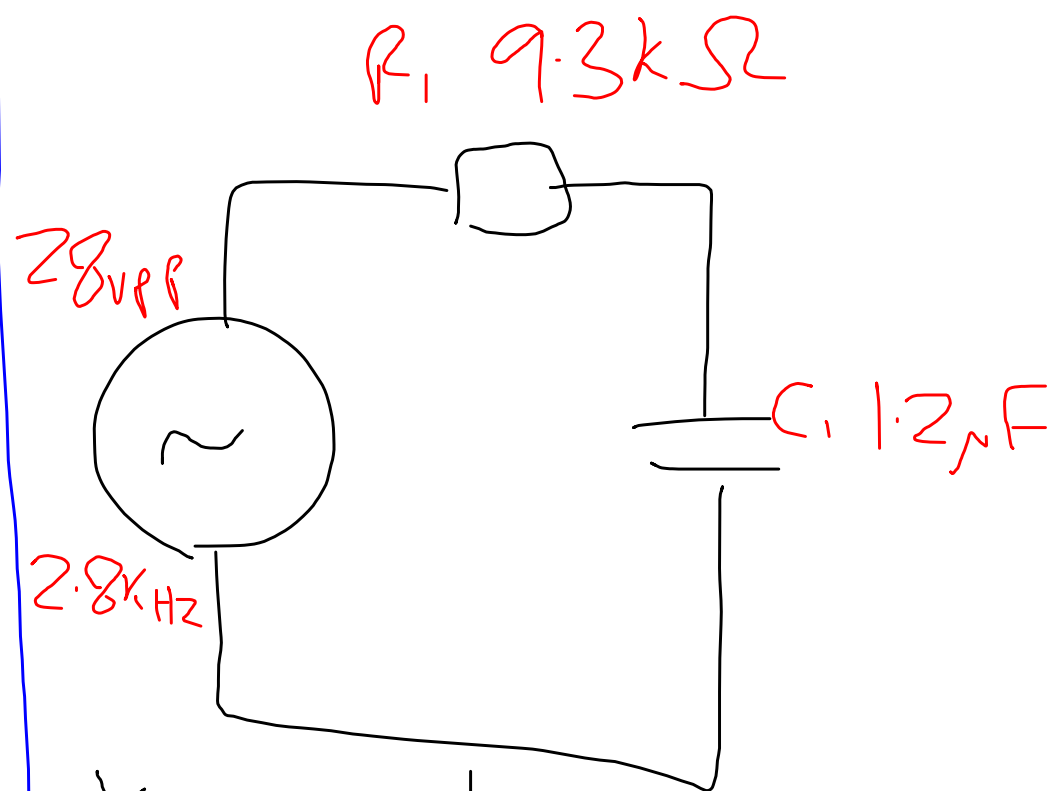
$$= \frac{1}{2\pi 50 1\mu F}$$

$$= 3.18k\Omega$$

FIND REACTANCES:



$$X_L = 2\pi 700Hz 50mH$$
$$= 219.91\Omega$$



$$X_C = \frac{1}{2\pi f C}$$
$$= \frac{1}{2\pi 2.8kHz 1.2\mu F}$$
$$= 47.37\Omega$$

IMPEDANCE
TOTAL OPPOSITION TO AC CURRENT
FLOW

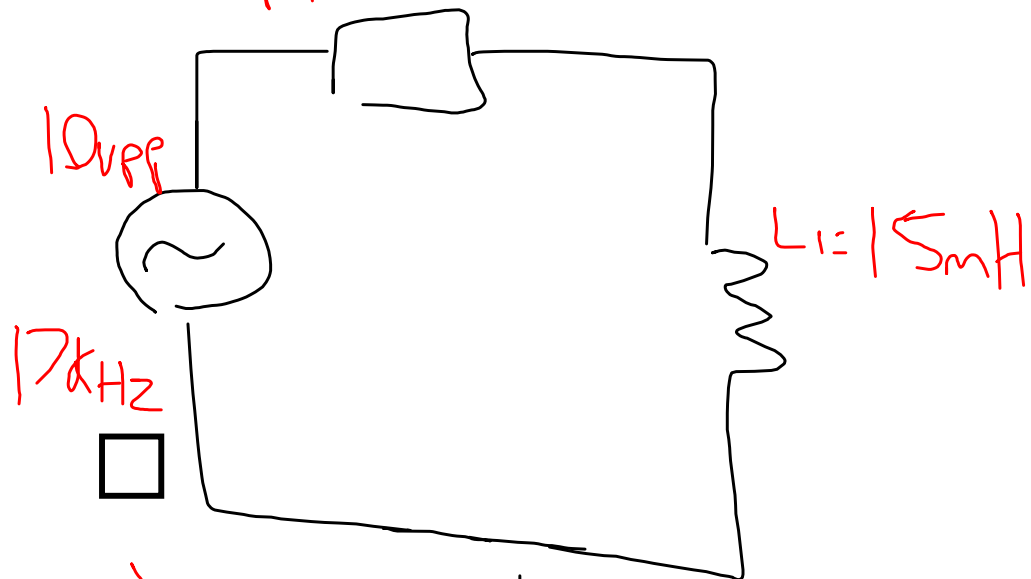
Z = IMPEDANCE WHICH IS
MEASURED IN OHMS.

IMPEDANCE IS YOUR CIRCUIT
RESISTANCE AND YOUR CIRCUIT
REACTANCE COMBINED.

SINCE THESE TWO ARE OUT OF
PHASE, WE NEED TO ADD
THEM VECTORIALLY

IMPEDANCE.

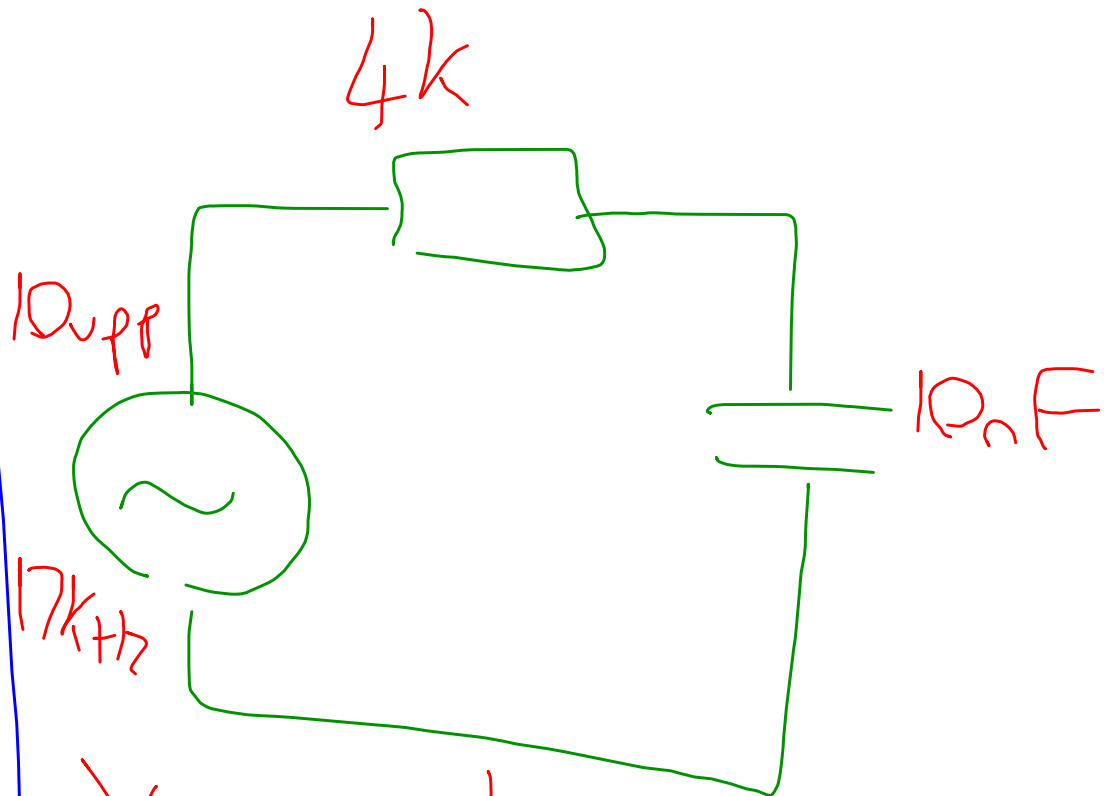
$$R_1 = 2.5 k\Omega$$



$$X_L = 2\pi 17kHz 15mH$$
$$= 1.6 k\Omega$$

$$Z = \sqrt{2.5k^2 + 1.6k^2}$$

$$Z = 2.97 k\Omega$$



$$X_C = \frac{1}{2\pi f C}$$

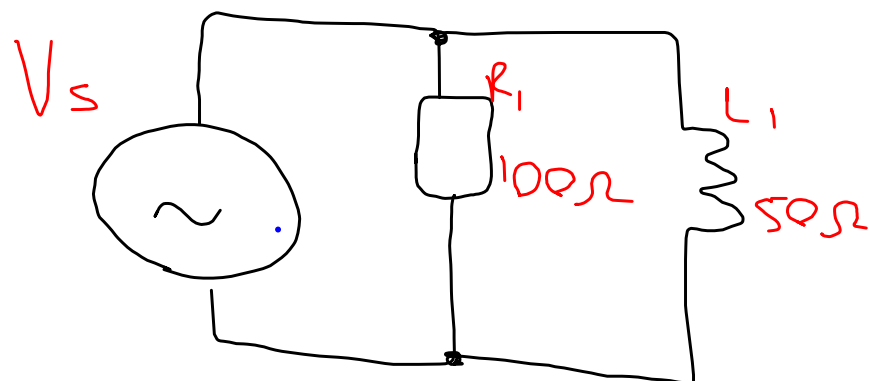
$$X_C = \frac{1}{2\pi 17kHz 10nF}$$
$$X_C = 936.21 \Omega$$

$$Z = \sqrt{4k^2 + 936.21^2}$$

$$Z = 4.11 k\Omega$$

IMPEDANCE

IN PARALLEL -



$$\frac{1}{\sqrt{\frac{1}{100^2} + \frac{1}{50^2}}} = 44.72 \Omega$$

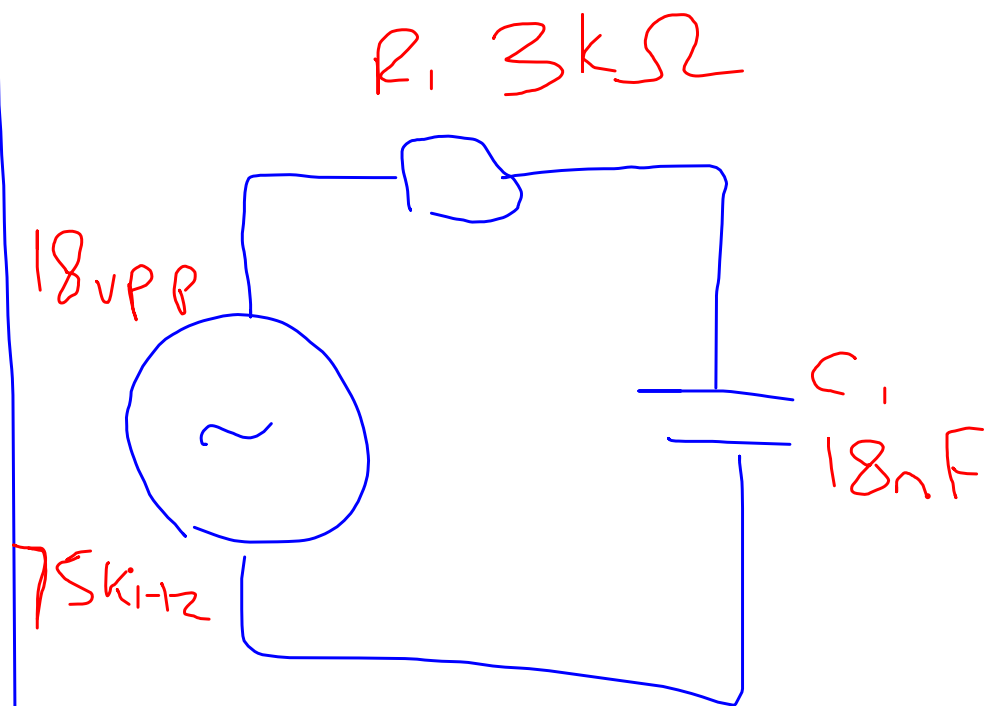
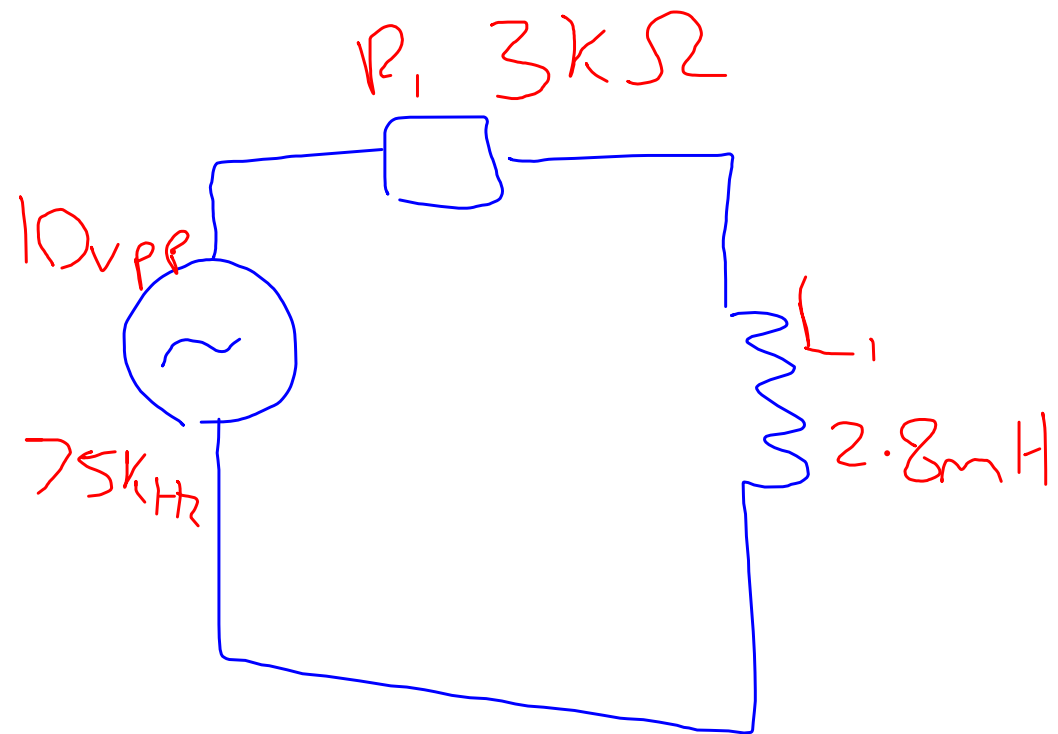
$$\begin{aligned} \theta &= \tan^{-1} \left(\frac{R}{X_L} \right) \\ \theta &= \tan^{-1} \left(\frac{100}{50} \right) \\ \theta &= 63.4^\circ \end{aligned}$$

$$\begin{aligned} Z &= \frac{R \cdot X_L}{\sqrt{R^2 + X_L^2}} \\ Z &= \frac{100 \times 50}{\sqrt{100^2 + 50^2}} \\ Z &= 44.72 \Omega \end{aligned}$$

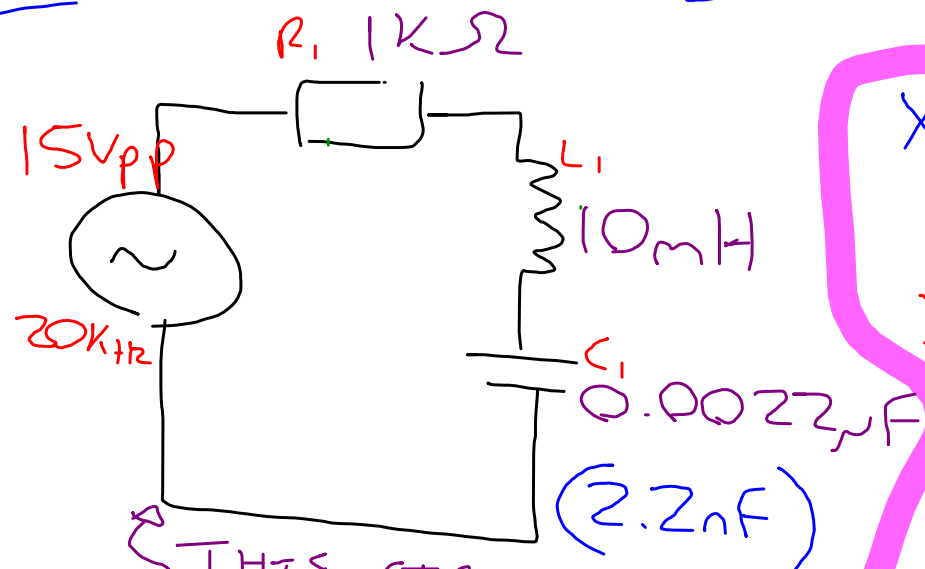
USE PRODUCT OVER SUM

OR
RECIPROCAL

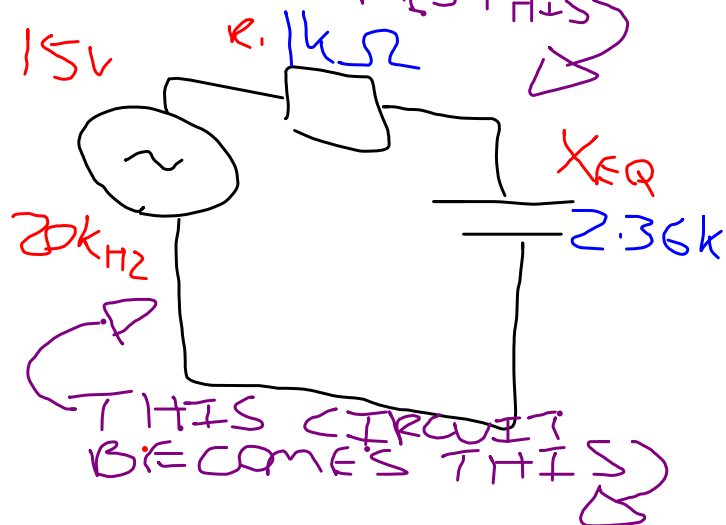
WHAT IS THE IMPEDANCE OF THESE?



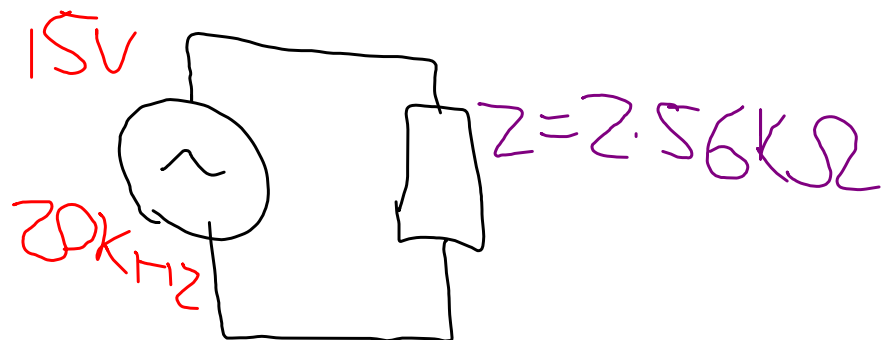
L < R CIRCUIT.



THIS CIRCUIT BECOMES THIS



THIS CIRCUIT BECOMES THIS



$$X_L = 2\pi fL$$

$$= 2\pi 20kHz 10mH$$

$$= 1.26k\Omega$$

$$X_C = \frac{1}{2\pi fC}$$

$$= \frac{1}{2\pi 20kHz 2.2nF}$$

$$= 3.62k\Omega$$

$$X_{EQ} = 3.62k\Omega - 1.26k\Omega$$

$$= 2.36k\Omega$$

$$Z = \sqrt{1k\Omega^2 + 2.36k^2}$$

$$= 2.56k\Omega$$

$$I_{TTP} = \frac{15V}{2.56k\Omega}$$

$$= 5.86mA_{pp}$$

$$V_{R1} = 5.86mA_{pp} \times 1k$$

$$= 5.86V_{pp}$$

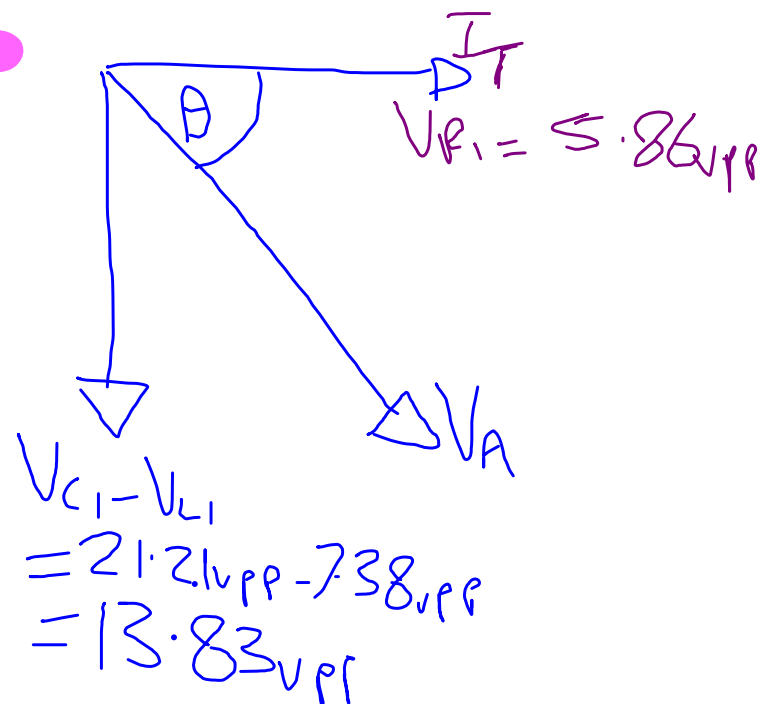
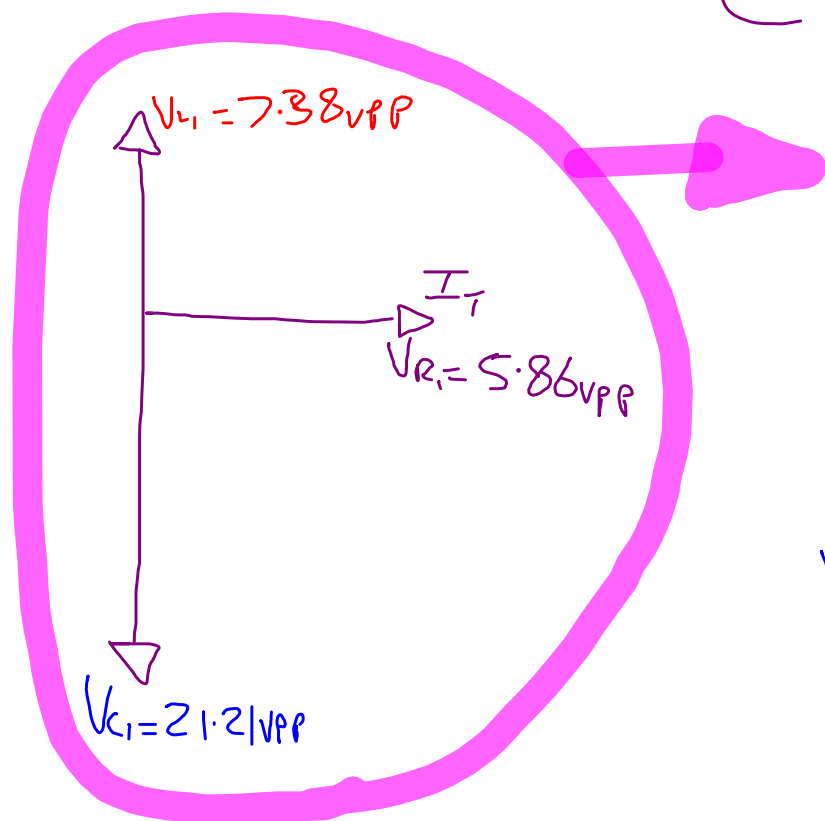
$$V_{L1} = 5.86mA \times 1.26k\Omega$$

$$= 7.38V_{pp}$$

$$V_C = 5.86mA_{pp} \times 3.62k\Omega$$

$$= 21.2V_{pp}$$

CIVIL



$$I_{T_{PP}} = \frac{15V}{2.56k\Omega}$$

$$= 5.86mA_{PP}$$

$$V_{R1} = 5.86mA_{PP} \times 1k$$

$$= 5.86V_{PP}$$

$$V_{L1} = 5.86mA \times 1.26k\Omega$$

$$= 7.38V_{PP}$$

$$V_{C1} = 5.86mA_{PP} \times 3.62k\Omega$$

$$= 21.21V_{PP}$$

$$\angle = \tan^{-1} \left(\frac{V_{C1}}{V_{R1}} \right) = 15V_{PP}$$

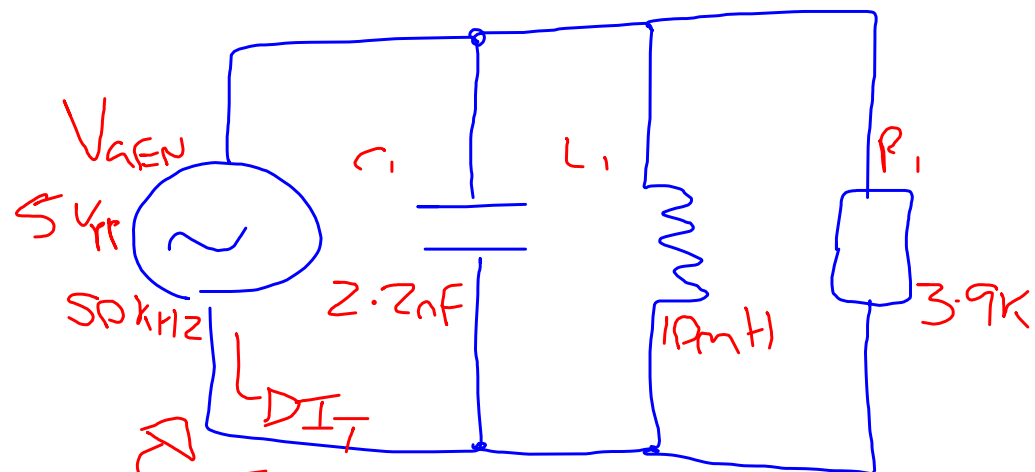
$$= \tan^{-1} \left(\frac{13.83V_{PP}}{5.86V_{PP}} \right)$$

$$= 67.07^\circ$$

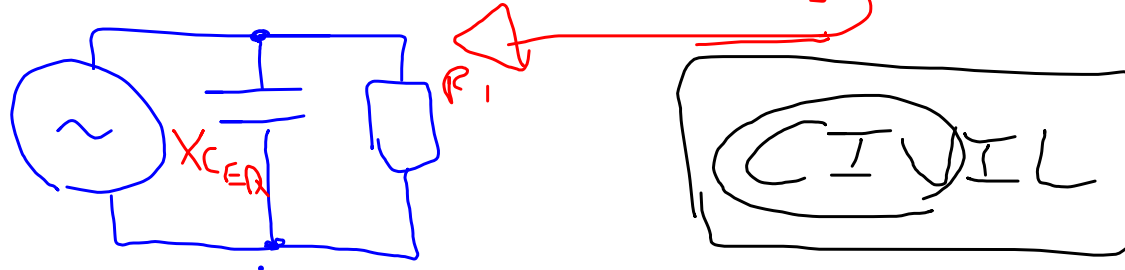
$$V_A = \sqrt{5.86^2 + 13.83^2}$$

$$= 15V_{PP}$$

PARALLEL LCR



THIS BECOMES THIS



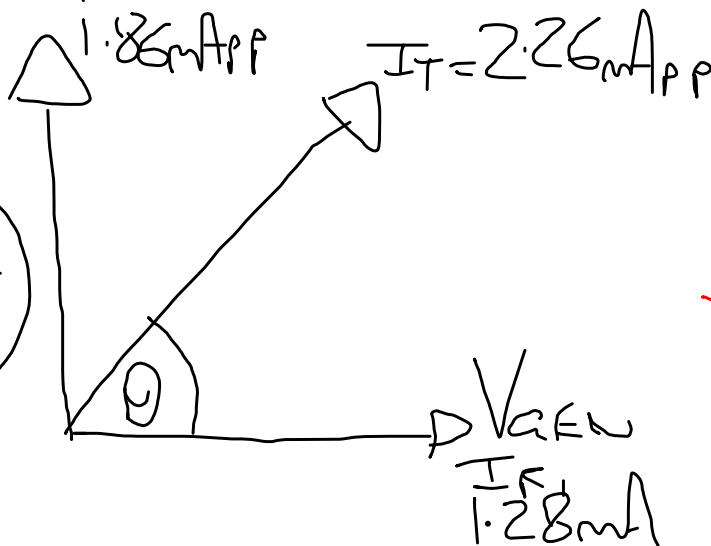
$$I_T = \sqrt{1.28\text{mA}_{pp}^2 + 1.86\text{mA}_{pp}^2}$$

$$= 2.26\text{mA}_{pp}$$

$$\theta = \tan^{-1} \left(\frac{I_{XEQ}}{I_{R_1}} \right)$$

$$= \tan^{-1} \left(\frac{1.86\text{mA}_{pp}}{1.28\text{mA}_{pp}} \right)$$

$$= 55.47^\circ$$



$$X_{L_1} = 2\pi 50\text{kHz} (10\text{mH})$$

$$= 3.14\text{k}\Omega$$

$$X_{C_1} = \frac{1}{2\pi 50\text{kHz} 2.2\text{nF}}$$

$$= 1.45\text{k}\Omega$$

$$I_{L_1} = \frac{5V_{pp}}{3.14\text{k}}$$

$$= 1.59\text{mA}_{pp}$$

$$I_{C_1} = \frac{5V_{pp}}{1.45\text{k}\Omega}$$

$$= 3.45\text{mA}_{pp}$$

$$I_{R_1} = \frac{5V_{pp}}{3.9\text{k}}$$

$$= 1.28\text{mA}_{pp}$$

since the current through the inductor is 180 degrees out of phase compared to the capacitor, we can simply take one away from the other to give us our reactive current. (we take the smaller value away from the bigger one)

$$I_{REQ} = 3.45\text{mA}_{pp} - 1.59\text{mA}_{pp}$$

$$= 1.86\text{mA}_{pp}$$

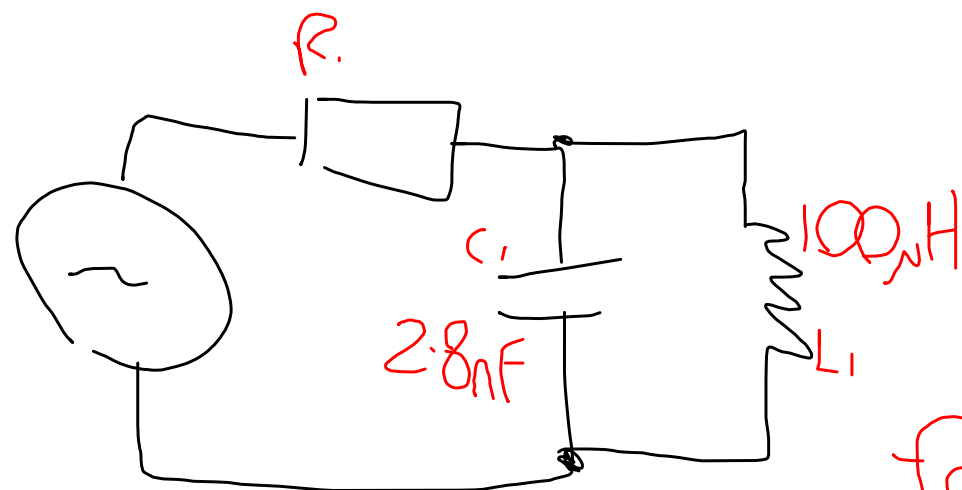
RESONANCE

resonance occurs when the capacitive reactance and the inductive reactance are exactly the same. In a series circuit, this causes maximum current to flow (short circuit). In a parallel circuit it causes minimum current to flow (open circuit)

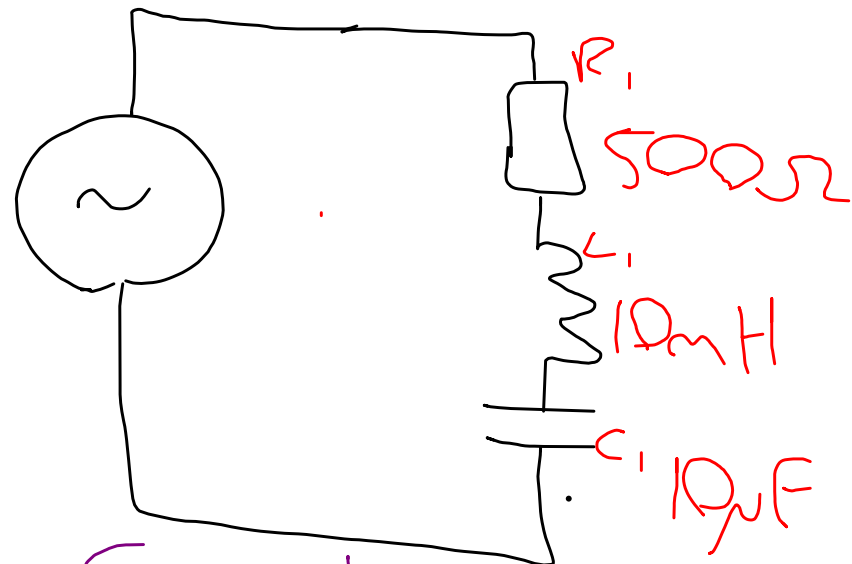
RESONANT
FREQUENCY

$$f_r = \frac{1}{2\pi\sqrt{LC}}$$

PARALLEL



SERIES



$$f_r = \frac{1}{2\pi\sqrt{10\text{mH} \cdot 10\text{uF}}} = 503.29 \text{ Hz}$$

$$f_r = \frac{1}{2\pi\sqrt{100\text{nH} \cdot 2.8\text{nF}}}$$

$$f_r = 300.77 \text{ kHz}$$

CIRCUIT Q

SERIES

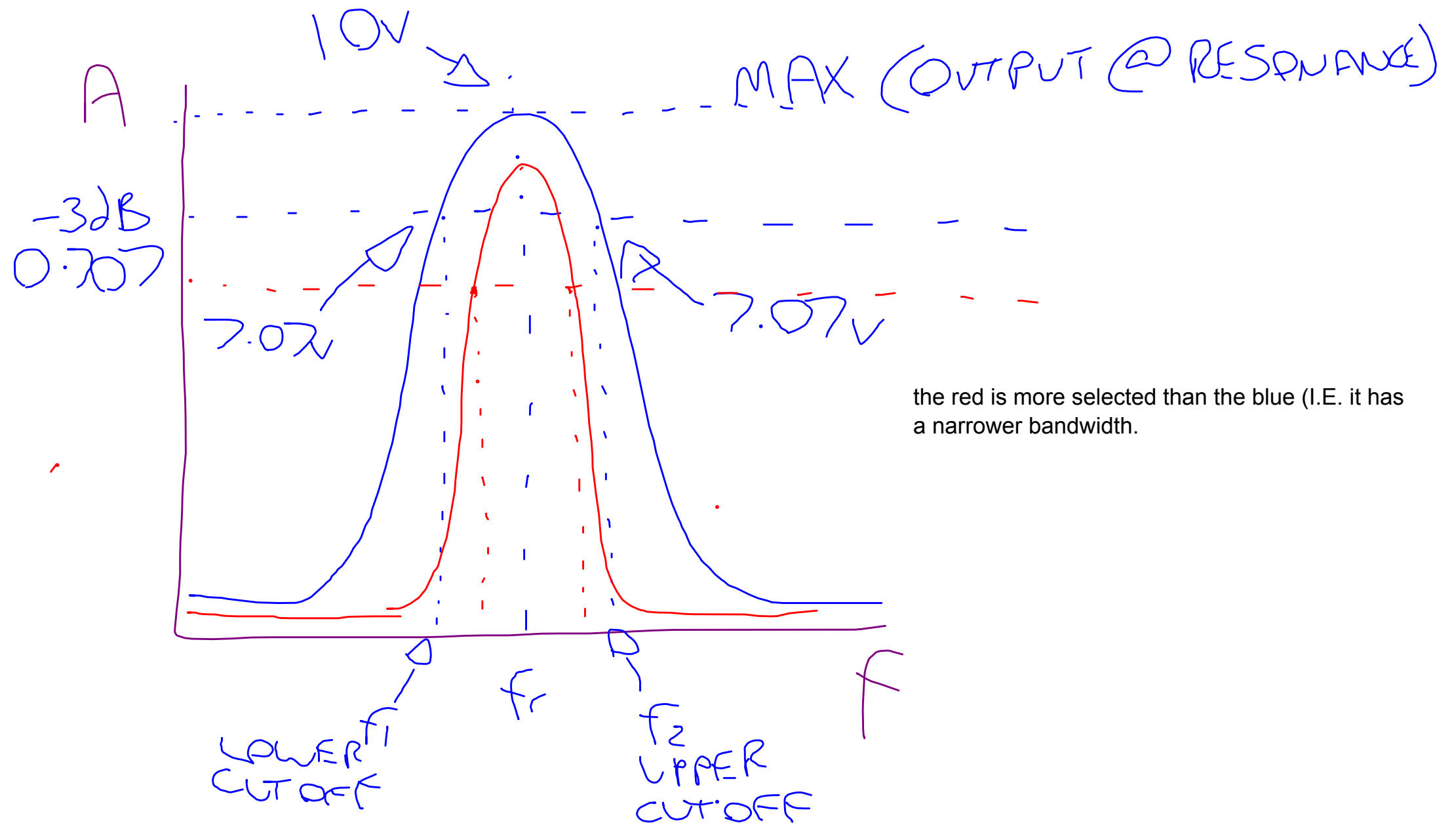
PARALLEL

$$Q = \frac{X_L}{R}$$

INDUCTIVE REACTANCE

RESISTANCE.

$$Q = \frac{R}{X_L}$$



the red is more selected than the blue (I.E. it has a narrower bandwidth).

$$BW = f_2 - f_1$$

