Dylan's PHYS230 Notes

Week 1

Lecture 1:
Intro
Theory

Imagine a charge Q moving through space: Qmoving

The change in potential energy is :

$$\Delta \mathrm{PE} = Q(V(B) - V(A))$$

$$\Delta V = \frac{\Delta PE}{Q}$$

Definition of units :

$$[V] = \frac{\text{joule}}{\text{coulomb}}$$

When talking gravitational Potential :

$$\Delta \mathrm{PE} = mg(z_0 + h) - mgz_0 = m(gh)$$

For now we will just say that ground is 0 volts.

The resistor in a circuit represents friction. IT dissipates potential energy as heat. So as the electrons go across a resistor they will lose potential energy, even if the voltage is held constant.

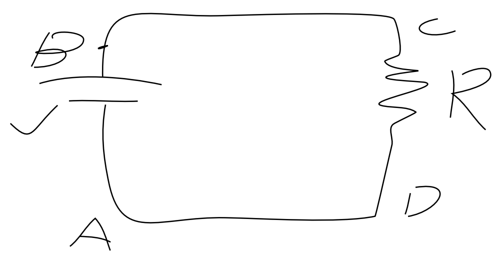

Figure 1: standardBRCircuit

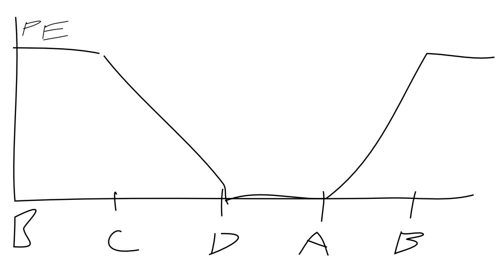

Figure 2: eneryGraphforStandardCircuit

Consider a wire :

How much charge dq flows by in a time dt? $\rightarrow$ current $= I = \frac{dq}{dt}$
Units :

$$[I] = \frac{\text{Coulombs}}{\text{seconds}} = \text{ Ampere } = A$$

SO what happens at a juntion?

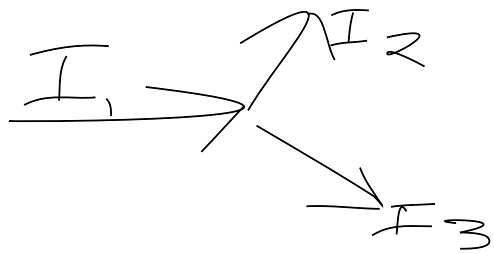

Figure 3: juntionKirchoff

Kirchoff's law : what goes in goes out :

$$I_0 = I_1 + I_2$$

Also known as

$$\sum_n I_n = 0$$

Ohm's Law :
The voltage drop across a resistor is proportional to the current flowing through.

$$V = IR$$

Resistance is a property of the material, there's a fundamental constant called ρ. This is unique to the material and simply serves to counter for the length and area :

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

Power is the rate of change of energy.

$$P = \frac{dE}{dt} = \frac{V dq}{dt} = IV$$

Kirchoff's Voltage Law : If you sum up all the voltages around a loop, they should sum to zero.

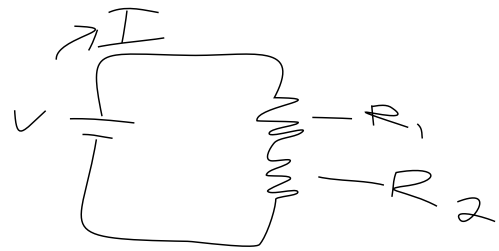

Figure 4: 2ResistorKirchoff

The current at all points will be the same on the single loop, however, the voltage will drop between each of the resistors.

For this circuit :

$$V = \Delta V_1 + \Delta V_2$$

We can then derive :

$$IR_1 + IR_2 = I(R_1 + R_2) = I(R_{eq})$$

This means that resistors in series add simply.

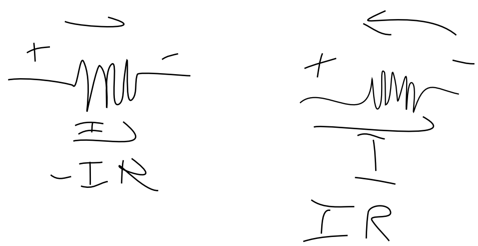

Figure 5: kirchoffSignConventions

Resistors in Parallel,

Figure 6: parallelResistorKirchoff

$$V = I_1 R_1 \implies I_1 = \frac{V}{R_1}$$

$$V = I_2 R_2 \implies I_2 = \frac{V}{R_2}$$

We can then use kirchoff's current rule :

$$I = I_1 + I_2 = V\left(\frac{1}{R_1} + \frac{1}{R_2}\right) = V\left(\frac{1}{R_{\text{ eq}}}\right)$$

When using the multimeter, volts are measured in parallel and current is measured in series.

Lecture 2: *1st Lab*

$$\frac{V_{\text{Ideal}}}{(R_s + R_l)} = \frac{\Delta V_L}{R_L}$$

For the 300 Ω Resistor:

$$\frac{9.58}{(R_S + 300\Omega)} = \frac{9.48}{300}$$
$$R_S = 3.16\Omega$$

For the 200 Ω Resistor

$$\frac{9.58}{(R_S + 200\Omega)} = \frac{9.44V}{200}$$
$$R_S = 2.967\Omega$$

Assuming that $R_S = R_L$

$$\frac{V_{\text{Ideal}}}{2R_S} = \frac{\Delta V_L}{R_S}$$
$$V_{\text{ ideal}} = 2V_L$$

This means that the ideal value is double what ends up being measured if the internal resistance is equal to the load resistor.

Oscilloscope notes :

At 10 ms/div, the waves are much tighter together. At 1ms/div the waves are much wider and details are much more visible.

The vertical scale modifies the amplitude of the sin waves.

The dial on the function generator is saying it is providing 100Hz, but the oscilliscope is reading 102Hz, so it's very likely a pretty accurate function generator.

given a period calculate a frequency, and convert the peak-peak voltage to both an amplitude and an RMS voltage

$$f = \frac{1}{P}$$

$$V_{\text{RMS}} = \frac{V_{\text{PP}}}{\sqrt{2}}$$

DC offset is measured by taking the amplitude of a wave, then taking the top "hemisphere" of the same wave. If the height of one positive region is exactly 1/2 the amplitude of the wave, then there is no DC offset. You can adjust for this DC offset with the vertical menu and then manual adjustment.

246V

Frequency with the resistor : 75MHZ The voltage clearly dropped a significant amount. The magnitude of the signwaves decreased and became significantly noisier.

Frequency directly from function gen → scope = 120hz Frequency through resistor → scope = 120hz

Output resistance is not frequency dependent. This is clearly due to the fact that the resistor is not time dependent.

Question 6.1 :

Voltage across the voltage source : 12.87

Voltage across the multi : 11.75

Resistor : 1 MΩ

$$V_L = \frac{V_0 R_L}{R_S + R_L}$$
$$R_0 = \frac{11.8(1)}{12.87 - 11.75}$$
$$R_0 = 10.5 \text{ M}\Omega$$

Lecture 3: *2nd Lab Start*

The frequency of AC line causes the oscilloscope to take measurements in accordance to the HZ of the power source on the oscilloscope. This means that the most stable readings from the function generator are found when measuring multiples of the power source frequency.

When using channel 1, adjusting the Level causes the oscilloscope at take it's snapshots at different times relative to the position on the wave form. This behavior seems to the same regardless of if the oscilloscope is in normal or auto mode.

The output of the TTL pulse is a square wave that allows for a triggering pattern that "syncs" with the function generator. This causes the oscilloscope to trigger very smoothly on the function generator's output.

Voltage accroding to the DC power source in the super board : 9.99V

Resistor resistance : 196.5ohms

Capacitor : 102.6μF

$$\frac{10}{e} = 3.67$$

Based on my equation for the logarithmically adjusted decay rate equation :

$$2.28 - 0.0459t = ?$$

Experimental $\tau \approx 21.0$

We can estimate the time constant at 21.4 because of the physical measurement. But using the capacitor equation we can find that time constant should be :

48.7329434697856

We have a log adjusted graph with the equation $2.28 - 0.0459$. So we can use this to estimate the time constant with some derivation :

$$V(t) = V_0 e^{-\frac{t}{\tau}}$$

$$\frac{V(t)}{V_0} = e^{-\frac{t}{\tau}}$$

$$\ln(\frac{V(t)}{V_0}) = -\frac{t}{\tau}$$

We can then substitue the slope from the equation easily because the slope is just $\ln(\frac{V(t)}{V_0})$:

$$-0.0459t = -\frac{1}{\tau}$$

Solving for τ gives : $\tau = 21.78$ which matches our experimental results very well.

Just multiplying the capacitance and the resistance together gives us τ =20.1609 which also matches the results quite well.

Since the dmm is in parallel with the rest of the circuit it's functioning to decrease the net resistance of the arrangement. Since the DAMS have a resistance of about 10MΩ, this would about equal the resistor meaning the effective resistance of the system would be about half what it should be. By splitting the resistance in half, the time constant would likely double.

3.1

9.98k Ω real resistance of 10kΩ resistor.

Cycle time : 14.9s Full charge and discharge.

$$\tau = 2\text{ms}$$

We can calculate the τ.

$$0.01\mu\text{F} \times 10 \text{ k}\Omega$$

$$0.0001\text{s}$$

3.2 Using a $0.1\mu F$ and $0.33\mu F$ capacitor set. The time constant was measured using the cursors : 6.28 - 3.28 = 3.00ms.

Scale height : $9 \rightarrow \frac{9}{e} = 3.3$. So I used the cursors to measure when the voltage had dropped to the 3.3rd scale on the y axis, indicating a decrease in voltage of $\frac{1}{e}$.

Based on calculation :

$$\text{parallel capacitors : } C_{\text{tot}} = C_1 + C_2$$

$$C_{\text{tot}} = 0.1\mu\text{F} + 0.33\mu\text{F} = 0.43\mu\text{F}$$

Using the same resistor from earlier.

$$9.98k \times 0.43\mu F = 4.29\text{ms}$$

So obviously our predicted time constant is a fair bit higher than the actual time constant. As our capacitors are "Old and shit" - Sander, there's a good chance that some of the capacitors have experienced dielectric decay or something that would reduce their function capacitance.

3.3 The capacitors were set up in series. The probe was placed with ground between the two capacitors, then ground leading past the second capacitor ($0.33\mu F$). The same procedure to measure decay time was repeated.

9 total ticks on vertical axis. So we want to find the 3.3 tick mark on the vertical axis and the time associated with this point. We measure a time constant of 1.04ms

$$\frac{1}{C_{\text{tot}}} = \frac{1}{C_1} + \frac{1}{C_2}$$

$$\frac{1}{C_{\text{tot}}} = \frac{1}{0.33} + \frac{1}{0.1}$$

$$\frac{1}{C_{\text{tot}}} = 13.03$$

$$C_{\text{tot}} = 0.076\mu\text{F}$$

We can then calculate :

$$9.98k\Omega \times 0.076\mu F = 756 \text{ s or } 0.756 \text{ ms}$$

4.1

Instead of using the breadboard, Sanders told me to just "be cool" and use 2 function generators. So Everything is based off of two function generators instead of the breadboard.

Used the -20dB setting and the attenuation modification to set the 2 low voltages for the scope.

Due to both waves having different frequencies, it's impossible to make both of them into "standing waves" unless they were set to multiples of each other. So instead, one of the waves has to be constantly "scrolling" depending on the trigger choice.

It's strange to describe the addition and subtraction modules, considering they're quite intuitive. However, since the triangle wave was so much stronger than the sine wave, the resulting waves always looked like triangle waves being traced by a sine wave. The type of wave seems to determine what shape is formed when you create a graph of 2 equal frequencies. The square wave produces lines, the sine wave makes circles, and the triangle makes rectangles. However the combination of these shapes can be interesting. I'm particularly a fan of the triangle and sine wave.

4.2

The XY mode is cool, managed to make a standing circle by perfectly matching the frequencies, but this slowly fell out of phase because the function generators aren't perfect.

5.1

PPV - 9.8V. $f = 204$Hz

Resistor real resistance : 300Ω

Tested frequency was 5.4 kHz

The resistor and capacitor are at a 90 degree phase offset from each other as measured by the oscilloscope with a ppv of 6.32V for the resistor, 6.8 for the capacitor, and 9.36 for the entire circuit.

Periods are all the same for all of the channels at 214μs

The τ is easily derived as $300\Omega \times 0.33\text{F} = 99\mu$s

Dropped frequency down by an order of magnitude to 549.6Hz:

Voltage drop across capacitors is much more powerful at lower frequencies than at higher frequencies. This is likely because the lower frequency gives the capacitor more time to charge and discharge, which causes larger voltage drops. At higher frequencies, the capacitor isn't able to cycle fast enough to impact the wave in the same way.

Review

I learnt how to use the cursors in a much more effective way in order to chart voltage decreases for the sake of measuring time constants.
The oscilloscope has many incredibly powerful tools that make lots of math and extra effort unnecessary. Tools like the offset and math functions can prove to be incredibly useful, the phase measurement proved to save a lot of time today.
Measuring otherwise unaccessible voltages through the subtraction and math tools were quite useful and will ikely be used again at a later time.
The XY oscilloscope tool allows for checking the symmetry of