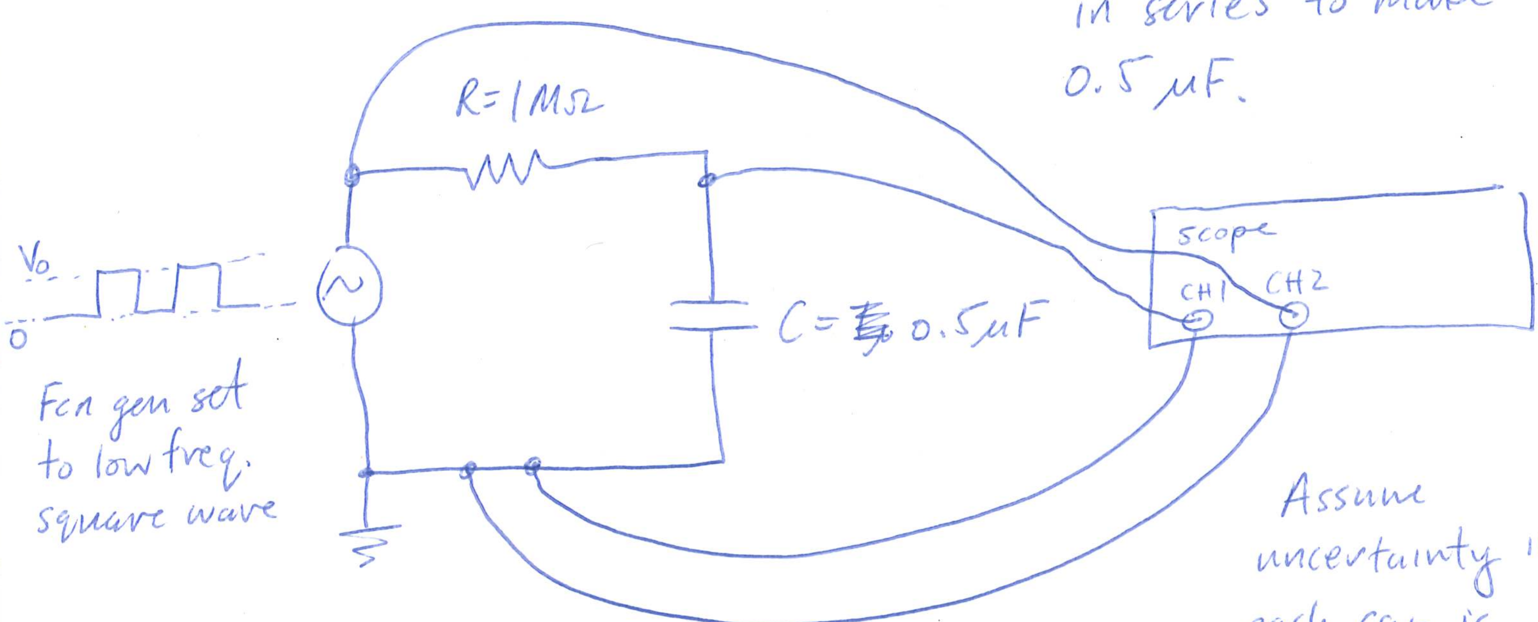
Sept. 20, 2019 ①

PHYS 231

Lab #3 - RC Transients.

Part 1.

Use two $1\mu F$ caps in series to make $0.5\mu F$.



Fcn gen set to low freq. square wave

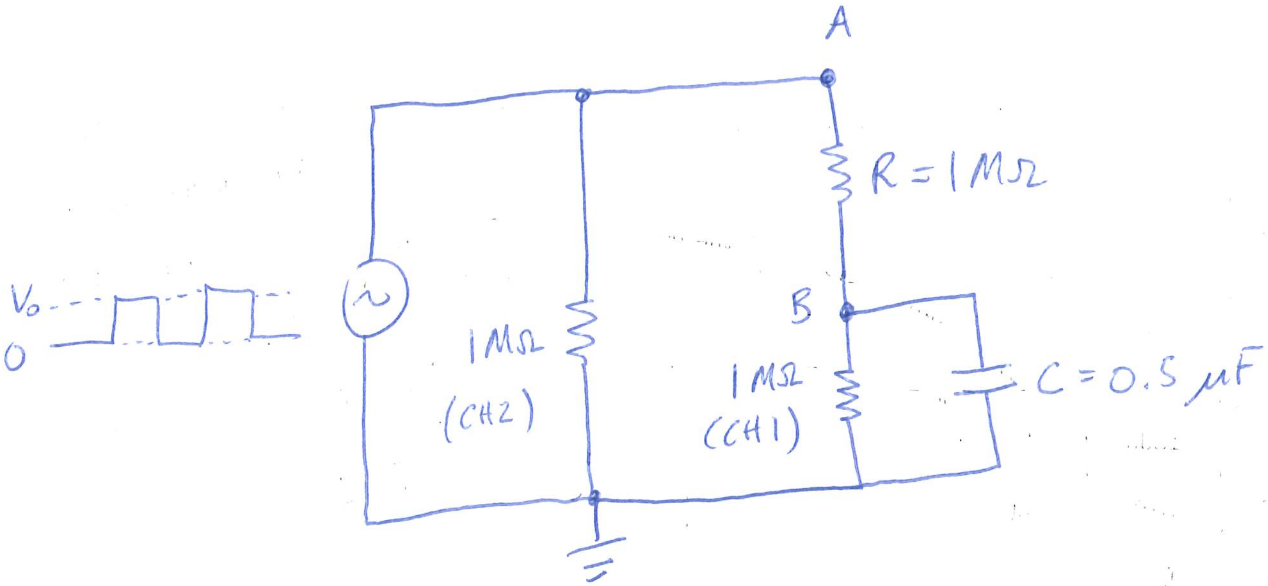
Assume uncertainty in each cap is ±5%

CH2 → V_{gen}.

CH1 → V_c

<u>Note</u>: Input impedance of osc. is 1 MΩ (each channel)

∴ The equivalent circuit is:



When square wave is "high", $V_A = V_0$ & $V_B = \frac{V_0}{2}$.

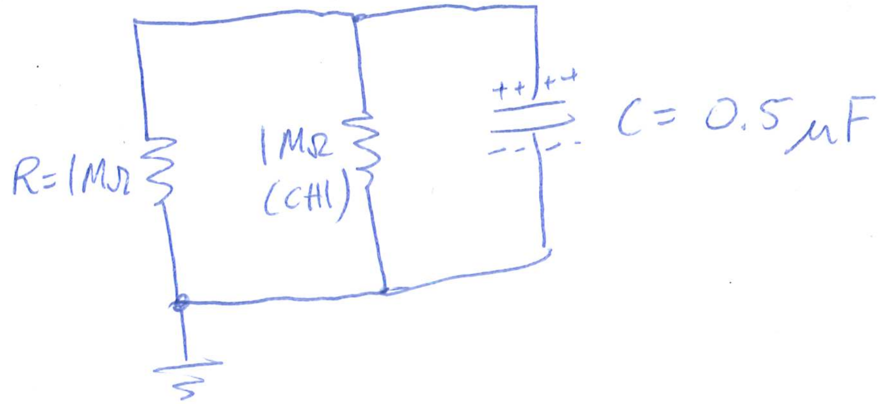
R & the $1\,M\Omega$ input impedance from CH1 create a voltage divider that makes the voltage a B half the volt. of the square wave when it is in its high state.

$\Rightarrow$ Cap only charges to $\frac{V_0}{2}$ (not V_0)

This fact is not really important for the purpose of the lab, but observant students might notice it & ask a question.

When the square wave is low, i.e. zero,

$V_A = 0$ & the equiv. circuit becomes

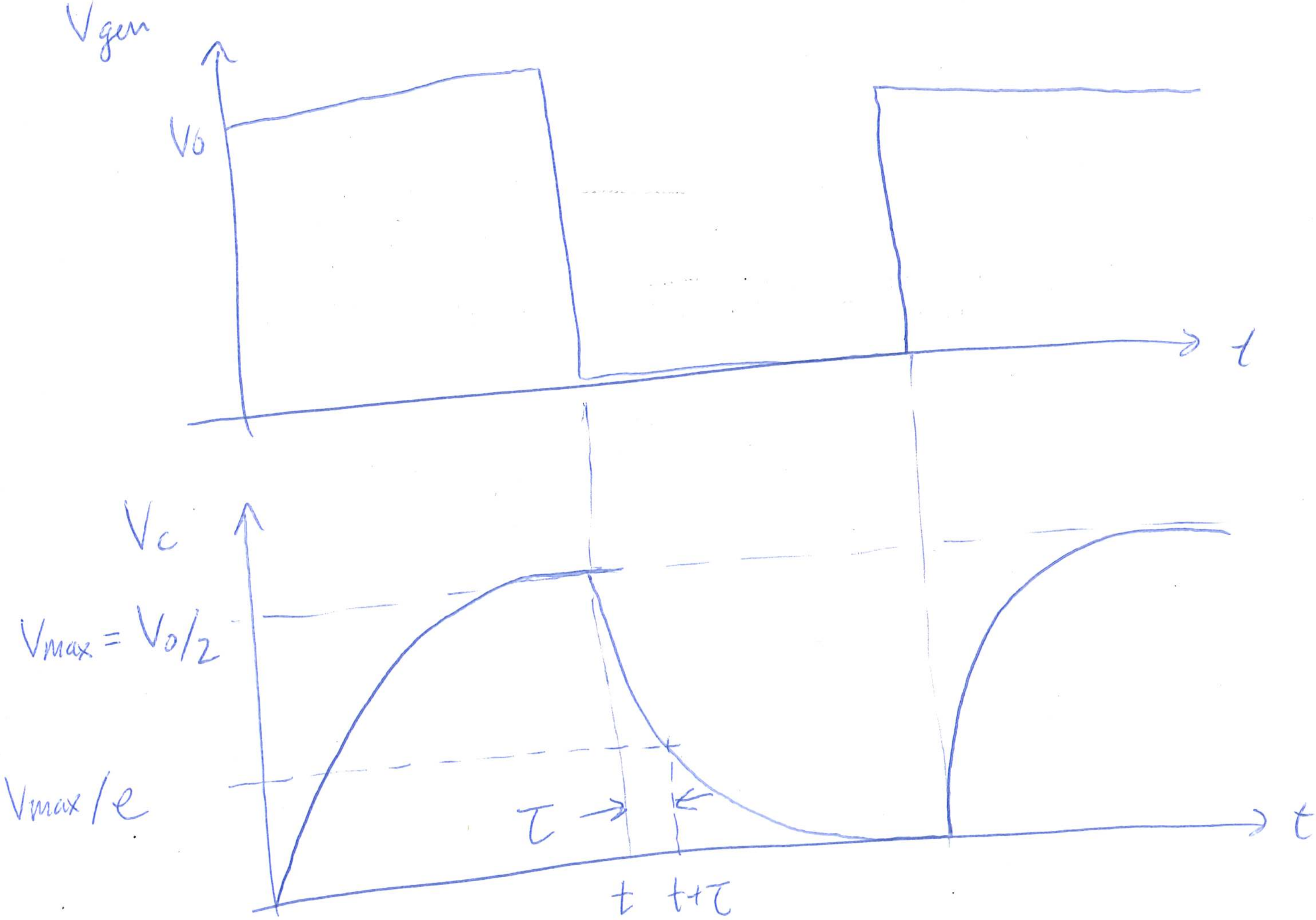


∴ C discharges through parallel combo of two 1MΩ resistors which is effectively $\underbrace{0.5\,M\Omega}_{R_{eff.}}$

When students meas. $\tau = RC$ in Part 1, they should be expecting $\tau = 0.5\,s$ & then meas.

$\tau_{meas} = R_{eff}C = 0.25\,s$. This should cause them to ask questions at which point you can remind them about the input impedance of the oscilloscope.

Meas. method for part 1.



To work, freq. of square wave must be very low.

require $T = \frac{1}{f} \gg \tau$

If expect $\tau = 0.5$ s, then need T to be at least 3 or 4 seconds. $\therefore f \approx 0.25$ Hz or lower.

When scope is properly set, students should measure max voltage of cap (V_{max}).

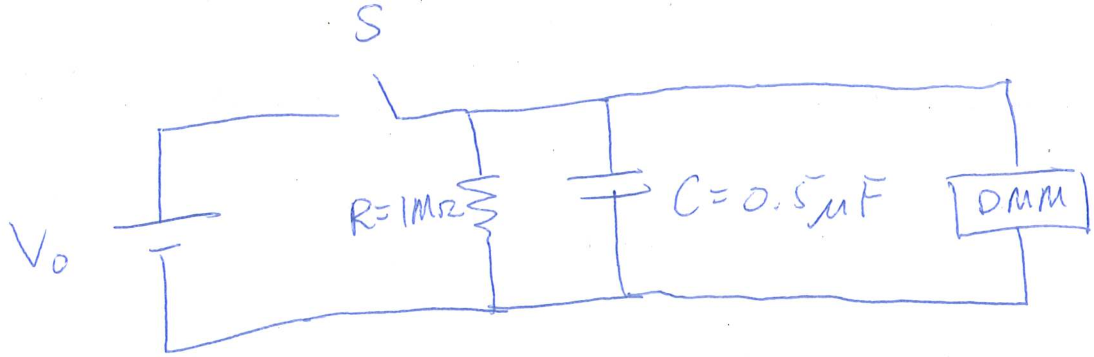
Since discharge is:

$$V_c(t) = V_{max} e^{-t/\tau}$$

If they find time when $V_c = \frac{V_{max}}{e}$, then they can deduce $\tau \rightsquigarrow$ the diff. in time when $V_c = V_{max}$ & $V_c = V_{max}/e$.

This is meant to be a quick meas. However, it will likely take students a lot of time to properly set up the scope.

Part 2



when S is close, C more or less instantly charges to V_o.

when S is open, C discharges through R with $\tau = RC = 0.5$ s.

(actually, input impedance of Agilent DMM is $10 M\Omega$.
$10 M\Omega \parallel R = 1 M\Omega = 0.909 M\Omega$ $\therefore$ expect $\tau \approx 0.45$ s)

We don't have a battery or a switch.

To make a constant voltage, lower the freq. range on PASCO fcn gen until "00000" displayed. Then turn the amplitude to max. The output is now a constant 10 V.

To mimic a switch, the banana cable can simply be pulled from the red terminal of the fcn generator.

To record data, the Agilent multimeters will need to be programmed to record 20 meas. of voltage with $\Delta t = 0.2s$ between each meas.

The data will be stored in the internal memory of the multimeter. After a successful trail, students can go into the ~~memory~~ menu to view the stored readings & copy them into their notebooks.

It would be a good idea for you to make sure you know how to program the meter and retreive stored data before the start of your lab.

In their write up, students should include a plot of $\ln V_c$ vs t & a weighted best fit. They should determine τ_{meas} $(\pm\Delta\tau_{meas})$ from the slope & compare to τ_{calc} $(\pm\Delta\tau_{calc})$

$$V_c = V_{max}\, e^{-t/\tau}$$

$$\ln V_c = \ln V_{max} + \left(-\frac{1}{\tau}\right) t$$

plot of $\ln V_c$ vs t has slope $m = -\frac{1}{\tau}$

if $y = \ln V_c$ $\quad \Delta y = \left|\frac{\Delta V_c}{V_c}\right|$

if $\tau_{meas} = \frac{-1}{m}$ $\quad \Delta\tau_{meas} = \left|\frac{\Delta m}{m^2}\right|$

if $\tau_{calc} = RC$ $\quad \Delta\tau_{calc}^2 = (C\Delta R)^2 + (R\Delta C)^2$