Data Tables

Signature of Lab Faculty: [signature] **Date:** 30/3/24

** *For all the data tables, take data up to three decimal places, round to two, and then enter into the table.*

Table 1: Resistance and Capacitance Data

For all your future calculations, please use the observed values only **(even for theoretical calculations)**.

Notation	Expected Resistance	Observed Resistance (kΩ)	Notation	Expected Capacitance	Observed Capacitance (μF)
R	1 kΩ		C_1	1 μF	0.978
			C_2	1 μF	0.967
			C_3	0.47 μF	0.4663

Table 2: Data from Circuit 1 *(Initial)*

Keep the switch to the **initial position** (connect to 2V and keep 6V open).

Initial Circuit	Initial DC Supply Voltage $V_S(0)$ (V)			$v_C(0)$ (V)	$v_R(0)$ (V)	$I(0) = \frac{v_R(0)}{R}$ (mA)
	Expected Voltage	From DC power supply	Using multimeter			
Experi-mental	2.0	2	1.976	1.973	0.27	~~0.027~~ 0.27
Theo-retical				2	0.3	0.3

Table 3: Data from Circuit 1 *(Final)*

Change the switch to the final position (connect to 6V and keep 2V open).

Final Circuit	Final DC Supply Voltage $V_S(\infty)$ (V)			$v_C(\infty)$ (V)	$v_R(\infty)$ (V)	$I(\infty) = \frac{v_R(\infty)}{R}$ (mA)
	Expected Voltage	From DC power supply	Using multimeter			
Experi-mental	6.0	6	5.92	5.8	0.00	0.00
Theo-retical				6	0	0

Table 4: Data from Circuit 2

Use the function generator for the supply voltage and observe all values from the oscilloscope.

Time constant, $\tau = RC =$ 1 *ms*

Theoretical charging / discharging time $= 5\tau = 5RC =$ 5 *ms*

Circuit 2	Supply Voltage V_S		Capacitor Voltage v_C		Charging / Discharging time t_{full} (ms)
	Minimum Value $V_{S_{min}}$ (V)	Maximum Value $V_{S_{max}}$ (V)	Minimum Value $v_{C_{min}}$ (V)	Maximum Value $v_{C_{max}}$ (V)	
Experimental (from oscilloscope)	2.04	6.12	2.04	6.12	4.75
Theoretical					

Table 5: Data from Circuit 3

Use the function generator for the supply voltage and observe all values from the oscilloscope.

Circuit 3	Charging Phase				Discharging Phase			
	Resistor Voltage		Circuit Current $I = \frac{v_R}{R}$		Resistor Voltage		Circuit Current $I = \frac{v_R}{R}$	
	$v_{R_{min}}$ (V)	$v_{R_{max}}$ (V)	I_{min} (mA)	I_{max} (mA)	$v_{R_{min}}$ (V)	$v_{R_{max}}$ (V)	I_{min} (mA)	I_{max} (mA)
Experi-mental	0	3.60	0	3.61	-3.76	0	-3.78	0
Theo-retical	0	3.5	0	3.5	-3.5	0	-3.5	0

Table 6: Data from Circuit 4 and Circuit 5

Use the function generator for the supply voltage and observe all values from the oscilloscope.

Amplitude of voltage to set on the function generator = 3.60 V

DC offset to set on the function generator = -3.76 V

Circuit 4	Capacitor Voltage v_C		Charging / Discharging time t_{full} (ms)	Time constant $\tau = \frac{t_{full}}{5}$ (ms)	Equivalent Capacitance		
	Minimum Value $v_{C_{min}}$ (V)	Maximum Value $v_{C_{max}}$ (V)			(from osc.) $C = \frac{\tau}{R}$ (μF)	From Circuit 5 using multimeter C_{eq} (μF)	Error $\frac{\lvert C-C_{eq}\rvert \times 100\%}{C_{eq}}$ (%)
Experi-mental	-2	3.04	4.85	0.97	0.974	0.97	0.412
Theo-retical			5	1	1	1	

Questions

1. A capacitor stores energy-

☐ Magnetically ☑ Electrically ☐ Chemically ☐ Electro-chemically

2. If the capacitance (C) of a capacitor is related with the voltage (V) and the current (I) of the capacitor as $C = \frac{q}{V}$, which one of the following statements is correct? The capacitance of a capacitor can be increased by–

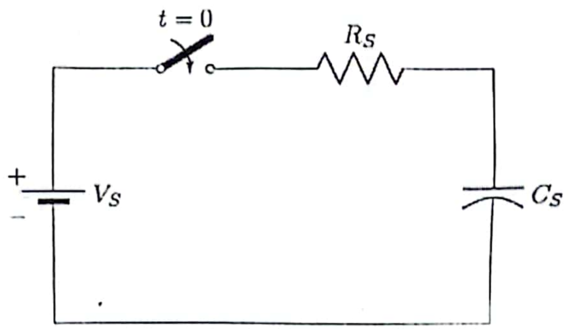
☐ decreasing the applied voltage across the capacitor.

☐ increasing the charge accumulation on the plates of the capacitor.

☑ increasing the surface area of the plates.

☐ decreasing the size of the capacitor.

3. When the switch in the following circuit is closed at $t = 0$, the following energy conversions happen–



[use the keywords electrical/mechanical/chemical/electro-chemical/thermal/heat to answer (a) (b) and (c)]

(a) The battery converts chemical energy to electrical energy.

(b) The capacitor receives electrical energy from the battery and stores in the form of electrical potential energy.

(c) The resistor dissipates energy into heat energy.

(d) Upon being fully charged by the battery (not to be dead so quickly), the capacitor–

☐ spontaneously releases the stored energy after some time to the resistor connected.

☐ gives the stored energy back to the battery after some time.

☑ holds the energy until some other circuit elements are connected to receive it.

☐ can better tell what it wants to do.

4. Why was it necessary to short the two terminals of a capacitor before measuring the capacitance in the laboratory?

Because Shorting the two terminal before measuring capacitance is crucial to discharge any stored, charge, ensuring safety, accurate measurements and preventing interference.

5. We know the time constant (τ) depends on the equivalent resistance and the capacitance as $\tau = R_{eq}C$. Let's say, for a particular circuit, under a certain dc bias, the time it requires for increasing the voltage of a capacitor from $0\ V$ to $5\ V$ is $5\ ms$. If there were an initial voltage in the capacitor equal to $2\ V$, would the time now to increase the voltage to $5\ V$ be the same?

☐ Yes ☑ No

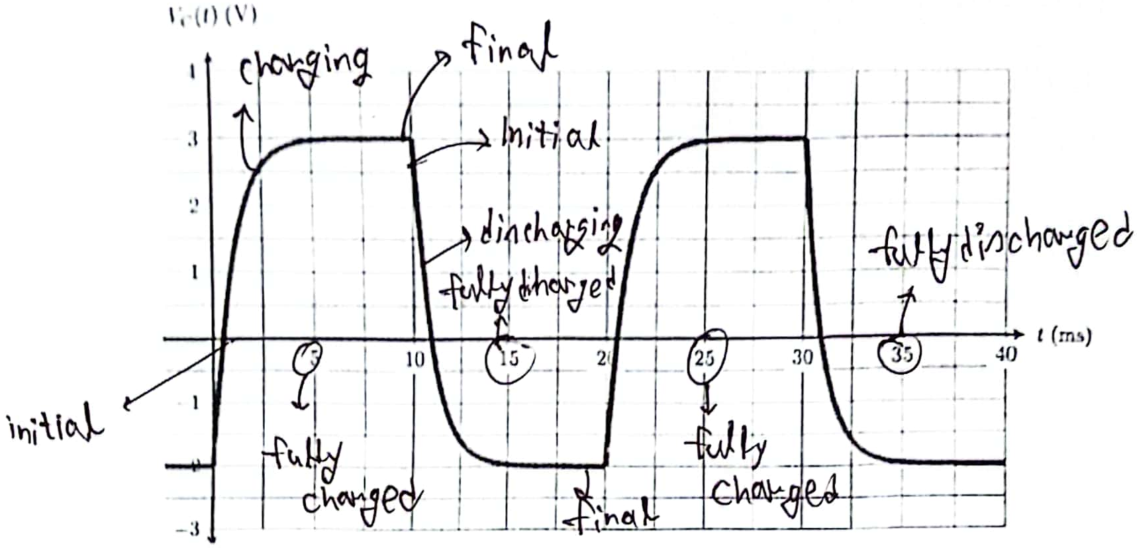
Why?

When there is an initial voltage on a capacitor it effects the charging process to the τ. This makes reaching a final voltage take longer compared to starting from 0V., As the initial voltage alters the charging rate.

6. Based on your understanding and choice in question 5, write briefly the significance of the time constant (τ) related to charging and discharging in an RC circuit.

The significance of τ is that An RC circuit signifies the rate at which a capacitor charges or discharges. A larger τ indicates slower charging/discharging. The smaller value indicates vice versa.

7. The capacitor voltage waveform you observed in the laboratory for **Circuit 3** is shown below where the input bias to the capacitance alternates between $-2\ V$ to $5\ V$ at a frequency of $100\ Hz$. The capacitor gets charged and discharged periodically.



(a) Mark the following things in the diagram:

(i) Charging and discharging phases (or timestamps)

(ii) The time constant (τ) for both charging and discharging phases

(iii) Initial and final voltages for both charging and discharging phases

(iv) The times when the capacitor gets fully charged and discharged.

(b) Explain how you can change the time-period of the voltage waveform keeping the duty cycle unchanged.

The time period of the waveform can be changed by altering or adjusting the width of the pulse (The time duration when the waveform is at the desired voltage)

(c) If the resistance in Circuit 3 is changed, will the duty cycle of the waveform change?

☑ Yes ☐ No

Why?

The shorter the time constant τ is, the faster the charging. Thus the duty cycle will increase.

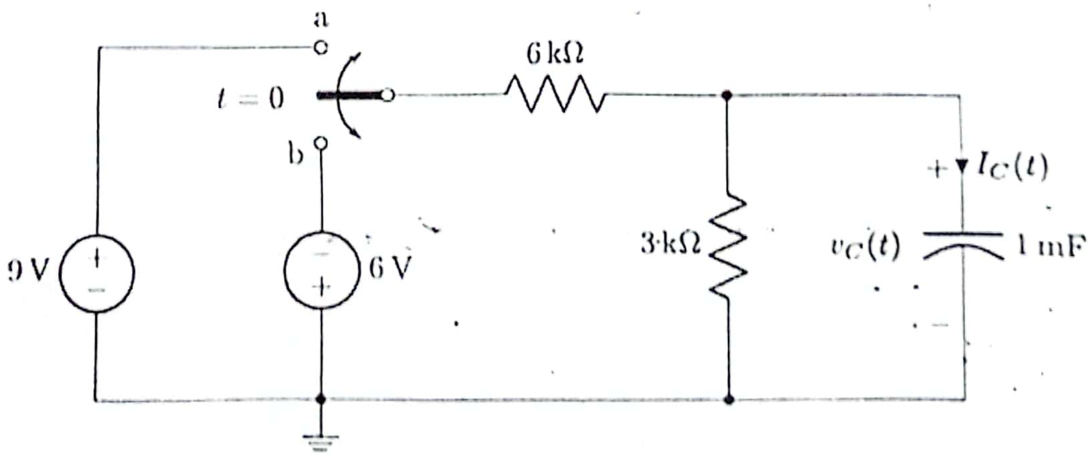
(d) Will decreasing the frequency of switching (slower switching) have any effect on the charging or discharging times of the capacitor?

Decreasing the frequency of switching will have ☐ no ☑ an effect on the charging and discharging time of the capacitor. Because an higher switching frequency means that the time available for each charging/discharging cycle decreases. As a result, the capacitor will have less time to fully charge or discharge between each cycle. This can lead to faster charge/discharge process compared to a lower switching frequency.

8. If you are asked to set a sinusoidal voltage with a dc offset $v(t) = 5 + 5sin(2\pi 100t)$ $(Volt)$ in a Function Generator, which of the following parameters do you need to set?
Select all that apply–

☐ Amplitude of the voltage, A =	5 V
☐ Peak to peak of the voltage, $2A$ =	10 V
☐ Natural Frequency, f =	100 Hz
☐ Angular Frequency, ω =	$rads^{-1}$
☐ Initial Phase, ϕ =	^{o}
☐ DC Offset =	5 V

9. Consider the RC circuit shown below. At $t = 0$, the switch starts to alternate between positions a and b at a frequency of 500 Hz.



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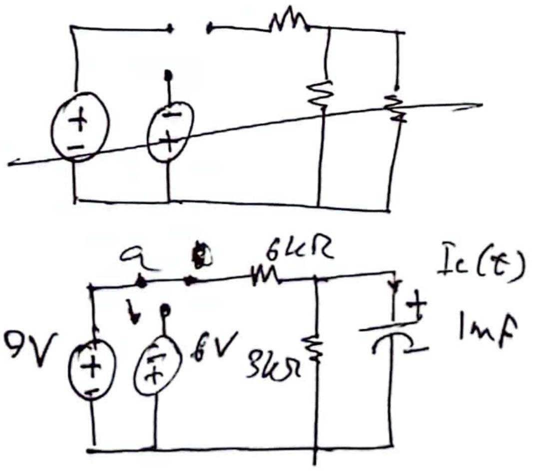
(a) Which one of the following instruments do you need in the laboratory to set up the switching mechanism between a and b as shown in the circuit diagram above?

- ☐ Two separate DC Power supplies.
- ☑ A Function Generator with the functionality of providing a dc offset.
- ☐ An Oscilloscope.
- ☐ A DC Power Supply with two channels.

(b) Based on your selection in (a) and the values of the input voltages in the circuit diagram, list down the parameters (amplitude, frequency, offset, scale, etc.) whose value you need to set on the selected instrument.
Select all that apply—

☐ Amplitude of the voltage, A =	5 V
☐ Peak to peak of the voltage, $2A$ =	V
☐ Natural Frequency, f =	500 Hz
☐ Angular Frequency, ω =	$rads^{-1}$
☐ Initial Phase, ϕ =	^{o}
☐ DC Offset =	1·5 V

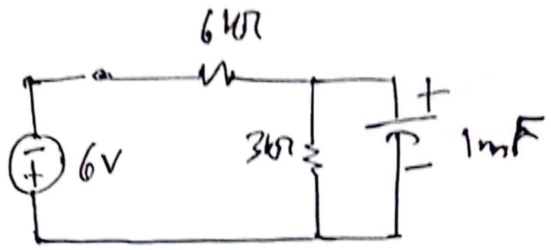
(c) Draw the active portion of the circuit when the switch is in position a and determine the voltage across the capacitor, $v_c(t, switch \rightarrow a)$. *See the Theory section of this sheet if necessary.*



$q = 1\times10^{-3} \times 9$
$= 0.009\ C$

$V = \frac{q}{C}$
$= \frac{0.009}{1\times10^{-3}}$
$= 9V$

(d) Draw the active portion of the circuit when the switch is in position *b* and determine the voltage across the capacitor, $v_c(t, \textit{switch} \to b)$. *See the Theory section of this sheet if necessary.*



$q = Cv = 1 \times 10^{-3} \times 6$

$= 0.006\,C$

$v = \frac{q}{C} = \frac{0.006}{1 \times 10^{-3}} = 6V$

(e) So, the capacitor voltage $v_c(t)$ alternates between the values ___9___ (V) and ___~~4~~ 6___ (V).

(f) Now, determine the equivalent resistance as seen from the capacitor terminals (for $t > 0$).

$R_{eq} =$ 2 $(k\Omega)$

(g) The time constant τ is thus–

$\tau = R_{eq}C =$ 2 (ms)

(h) If the time constant (τ) is ___2___ (ms), it will take ___~~8~~ 10___ (ms) for the capacitor to be fully charged or discharged.

(i) In general, the voltage across a capacitor under a sudden change in the applied dc bias is,

$$v_c(t) = v_c(final) + [v_c(initial) - v_c(final)]e^{-\frac{t}{\tau}}$$

or

$$v_C(t) = v_C(\infty) + [v_C(0) - v_C(\infty)]e^{-t/\tau}$$

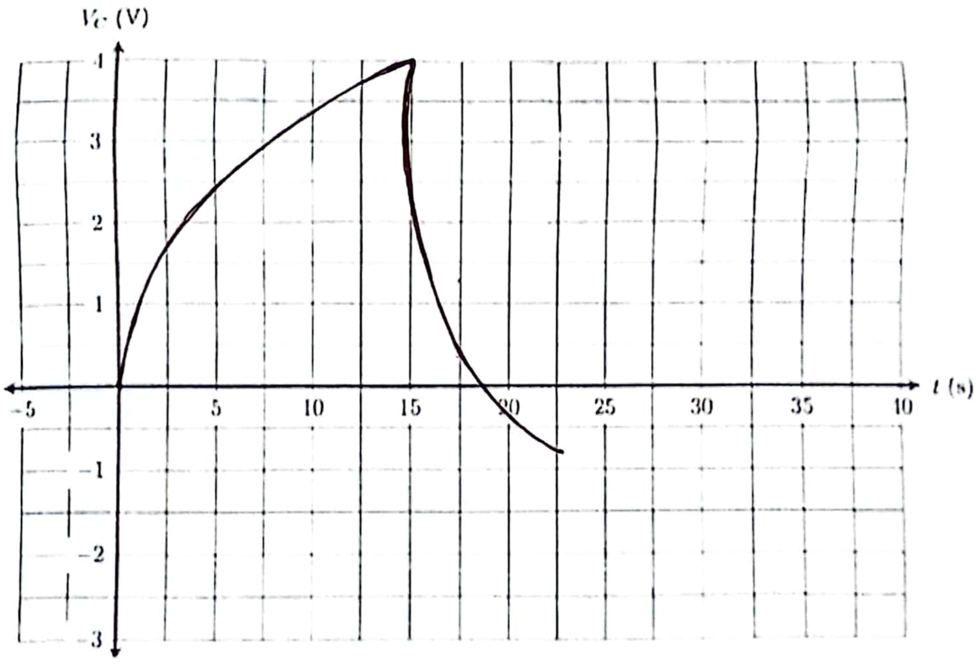
So, when $v_C(final) > v_C(initial)$, the capacitor gets charged and when $v_C(final) < v_C(initial)$, the capacitor gets discharged.

Based on this criteria, plug in the values you got in (e) and (g) appropriately in the equation for $v_C(t)$ and write down the expression of $v_C(t)$ as a function of time for–

Charging: $v_C(t) =$ $9 + (6-9)\, e^{-t/\tau}$

Discharging: $v_C(t) =$ $6 + [9-6)\, e^{-t/\tau}$

(j) Given the frequency of switching 500 Hz, based on the values in (e) and (h), draw the waveform of the voltage across the capacitor v_C for $t > 0$, that we could observe in an Oscilloscope as a function of time as it gets charged and discharged continuously.



Report

1. Fill up the theoretical parts of all the data tables.
2. Answers to the questions.
3. Attach the captured images of the plots observed in the oscilloscope for **Circuits 2, 3,** and **4.** Fit all the images in a single page and print.

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