EXPERIMENT 07

TO STUDY DC RC CIRCUIT AND TRANSIENT PHENOMENA

DISCUSSION

The capacitor is a element which stores electric energy by charging the charge on it. Bear in mind that the charge on a capacitor cannot change instantly. Fig. 1 shows a basic RC circuit consisting a dc voltage, switch, capacitor, and resistor. Assume that the voltage across C is zero before the switch closes. Even at the instant when the switch closes (connecting to VR1 and letting VR1 = R), the capacitor voltage will still be at zero, and so the full voltage is impressed across the resistor. In other words, the peak value of charging current which starts to flow is at first determined by the resistor. That is, $I_o = V/R$.

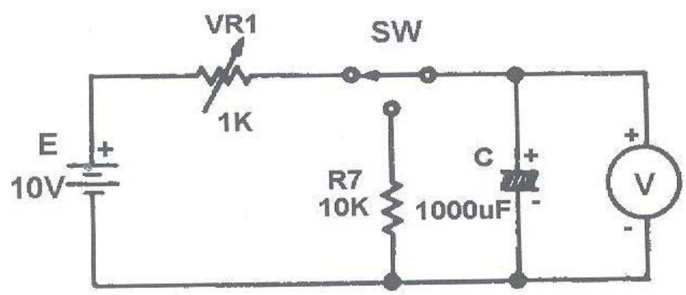


Figure -1

As C begins to charged, a voltage is built up across it which bucks the battery voltage, leaving less voltage for the resistor. As the charging continues, the current keeps decreasing. The charging current can be expressed by the formula $\mathbf{i = (V/R)\acute{\varepsilon}^{-t/RC}}$, where $\acute{\varepsilon} = 2.718$. Fig.2 shows how the charging current varies with time.

Fig.3 shows how the resistor voltage V_R and the capacitor voltage $\mathbf{V_C}$ vary with time when it is charging. The capacitor voltage V_C is expressed by $\mathbf{V_C = V(1- \acute{\varepsilon}^{-t/RC})}$ and the resistor voltage is $\mathbf{V_R = V\acute{\varepsilon}^{-t/RC}}$ by Kirchhoff's voltage law, $\mathbf{V = V_R + V_C}$ at all times.

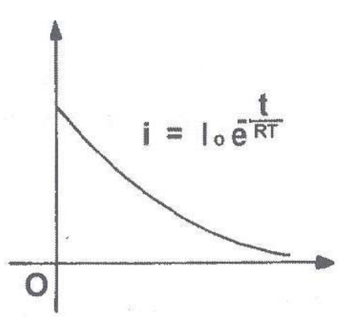


Figure -2

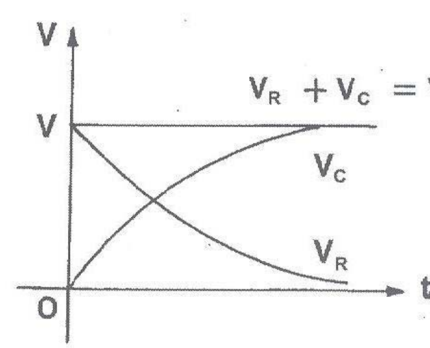


Figure-3

For the moments we assume that the VC is equal to the battery voltage. The switch is switched to connect the C and R7 in shunt. The capacitor then discharges through R7 (letting R7=R), so the discharging current, the resistor voltage, and the capacitor voltage can be expressed by the following:

$$L = -(V/R)\ \acute{\varepsilon}^{-t/RC} \qquad V_C = V\ \acute{\varepsilon}^{-t/RC} \qquad V_R = V-\ \acute{\varepsilon}^{-t/RC}$$

Fig 4 shows how the discharging current varies with time. Fig.5 shows how the V_R and V_C vary with time when it is discharging.

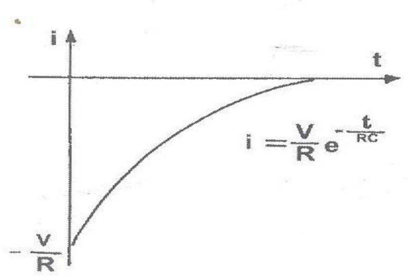


Figure – 4

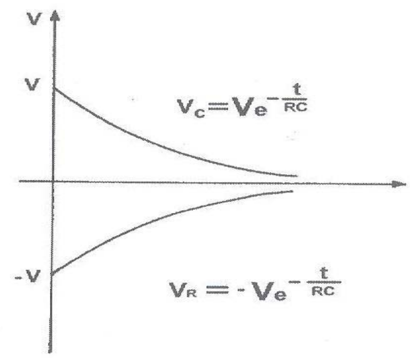


Figure- 5

When the capacitor charges, the final value of Vc is determined solely by battery voltage, and how long it takes to get there depends on the resistor and capacitor sizes. The value of RC product is referred to as the time constant (T or TC) of the RC circuit. That is, T= RC, where T is second, R in ohm, and C in farad. If t= 1T, the capacitor will build up to 63% of this final voltage. The time constant chart is shown in Fig.6 curve as the capacitor charge voltage and curve B is the capacitor discharge voltage. In practice, at t = 5T, we can consider that the Vc charges to V or Vc discharges to 0

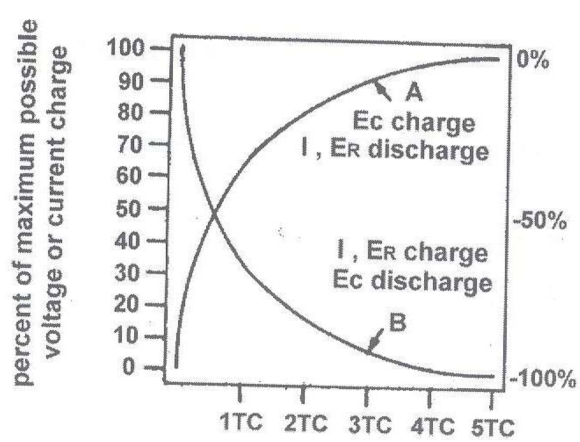


Figure - 6

PROCEDURE

1. Set the module KL-21001, and locate the block d.
2. According to figs.1 And 7 complete circuit with short- circuit clips.

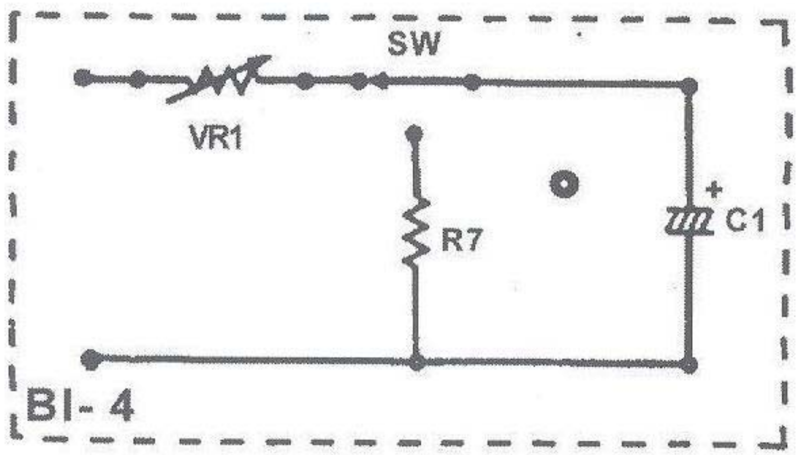


Figure - 7

3. Adjust VR1 to 1 KΩ. Turn the switch to VR1 position.
   Connect the voltmeter across the capacitor C1.
   Adjust the positive to +10V and apply it to circuit.
   At this instant the capacitor C1 begins to charge and the capacitor voltage Vc1 increases and finally reaches to 10V as indicated by the voltmeter.

4. Turn the switch to R7 position.
   The capacitor begins to discharge and the Vc decreases to 0V.

5. Using the equation T= RxC and the values of VR1 and C1 calculate the time constant
   T = _______________Sec.

6. Calculate the values of charging capacitor voltage Vc1 at t = 0T, 1T, 2T, 3T, 4T, and 5T and plot them on the graph of fig.8.
   Draw a smooth curve through these plotted points.

This will be a charging curve.

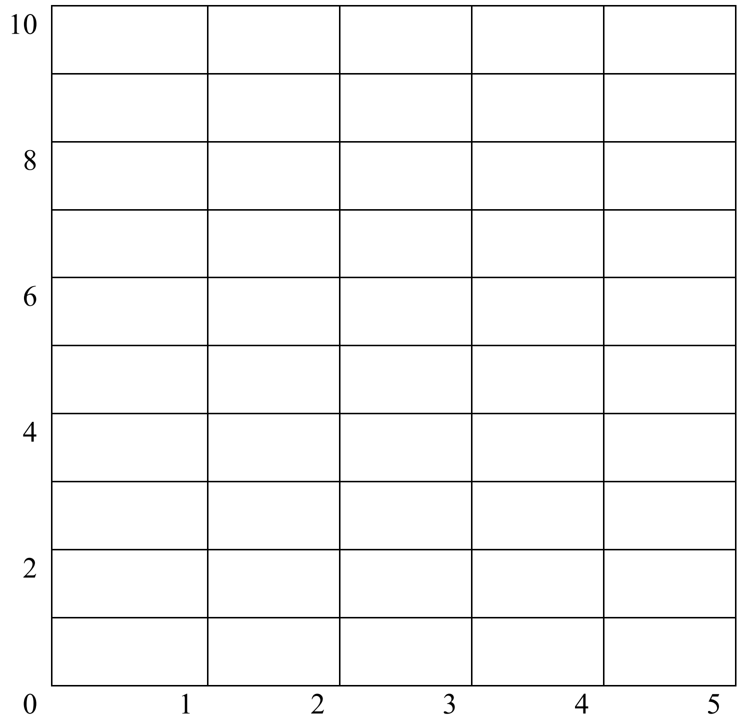


Figure-8

7. Use the stopwatch to count the time constant or oscilloscope.
   Turn the switch VR1 position, measure and record the time when the charging capacitor voltage Vc1 reaches 6.32V as indicated by the voltmeter.
   T=______________Sec.
   Note: Make sure Vc1= 0 before changing the capacitor each time.

8. Measure the values of Vc1 at time t= 1T, 2T, 3T, 4T, 5T, and record the result in table 1.

TABLE-1

Time (t)	**0T**	**1T**	**2T**	**3T**	**4T**	**5T**
V_C1						

9. Plot the recorded values of t and Vc1 on the graph of Fig.8, and then draw a smooth curve through these plotted points.
10. Comparing the curves of steps 9 and 6, is there good agreement between the two
    ☐Yes ☐No

11. Adjust VR1 to 200Ω.

    Calculated and record the time constant T.

    T= _________Sec.

    Charge the capacitor and observe the charge in Vc1 indicated by the voltmeter.

    Is the charging time shorter than that of step 3 for Vc1 = 10V?

    □Yes □No

12. Turn the switch to the VR1 position.

    Apply the power + 10V to charge the capacitor to Vc1 = 10V.

13. Turn the switch to R7 position. The capacitor will discharge through R7.

    Calculated and record the time constant for discharging.

    T =_________________Sec.

14. Repeat step 6 for discharging curve.
15. Measure and record the time that Vc1 decreases from 10V to 3.68V.

    T =_________________Sec.

    Comparing this result with step 13, is there agreement between the two?

    □Yes □No

16. Repeat step 8 for discharging and record the result in table 2.

TABLE-1

Time (t)	**0T**	**1T**	**2T**	**3T**	**4T**	**5T**
V_C1						

17. Repeat step 9 for discharging curve.
18. Comparing the curves or steps 17 and 14, is there good agreement between the two? □Yes □No

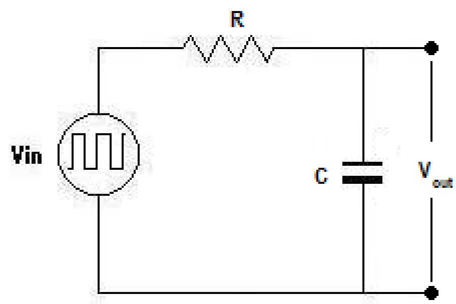
EXPERIMENT 08

TO STUDY THE PULSE RESPONSE OF A SERIES RC NETWORK

EQUIPMENT

1. Signal generator
2. Oscilloscope
3. Capacitor: 0.1µF / 0.001µF
4. Resistor: 10KΩ / 20 KΩ

CIRCUIT DIAGRAM



THEORY

The step response of a network is its behaviors when the excitation is the step function. We use a square wave source, which in fact repeats the pulse every ‘T’ Seconds and allows a continuous display of repetitive responses on a normal oscilloscope.

Charging a capacitor

We investigate the behavior of a capacitor when it is charged via a high resistor. At the instant when step voltage is applied to the network, the voltage across the capacitor is zero because the capacitor is initially uncharged. The entire applied voltage v will be dropped across the resistance R and the charging current is maximum.

But then gradually, voltage across the capacitor starts increasing as the capacitor start to charge and the charging current starts decreasing. The decrease of the charging current and the increase of voltage across the capacitor follow exponential law.

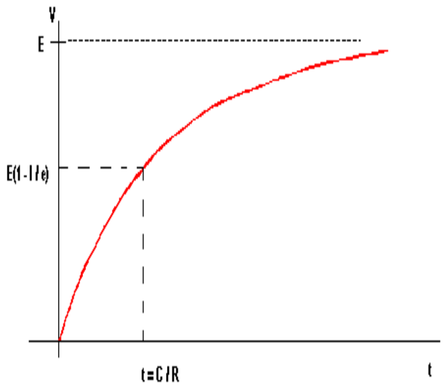
$$I(t) = V/R\ e^{-t/RC}$$

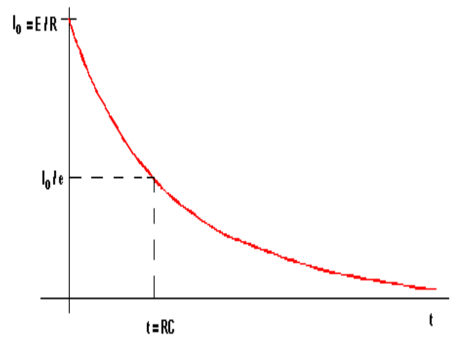
However, the voltage across the capacitor is given by,

$$V_C\ (t) = V\ (1- e^{-t/RC})$$

Where t= time elapsed since pulse is applied

τ = RC= Time constant of the circuit



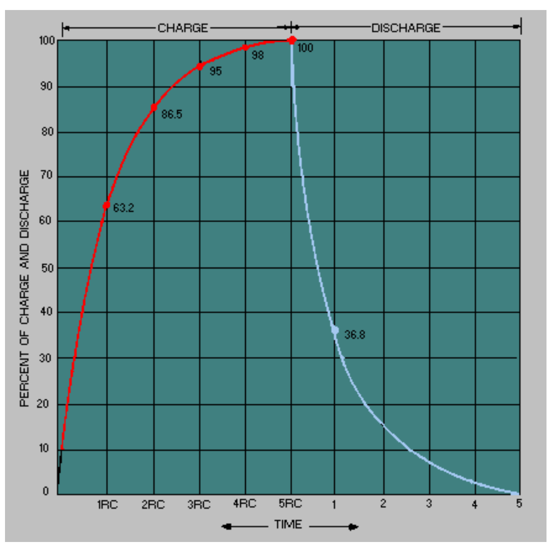


Discharging a charged Capacitor

During the next half cycle of pulse, when the pulse amplitude is zero and capacitor is charged to potential difference of V volts, now the capacitor discharges through resistor R. So, the voltage across capacitor decreases exponentially and the discharge current rises instantly to a maximum value i.e Im=V/R and then decays exponentally. Mathematically, it can be shown that voltage across the capacitor and discharging current are given value by,

$$V_C\,(t) = V\,e^{-t/CR}$$

$$I(t) = -I_m\,e^{-t/RC}$$



PROCEDURE:

1. Set the out of the function generator to a square wave with frequency 500Hz and peak to peak amplitude 5V.
2. Wire the circuit on bread board.
3. Display simultaneously voltage V_{in} (t) across the function generator (on CH1) and V_C (t) across the capacitor C (on CH2).
4. Sketch the two measure wave forms V_{in}(t) and V_c (t), calculate and sketch the waveforms, V_R(t) and I (t). Label the time, voltage and current scales note that the voltage across the R is V_R (t) also represents the current I (t).
5. Measure the time constant τ, using the waveform V_C (t). Expand the time scale and measure the time it takes for the waveform to complete 63% of its total change, i.e 5V. Enter the measured value of τ in table.
6. Computer values of theoretically expected and experimentally obtained time constants τ.

Max frequency input pulse that can be applied:

If the pulse width is at least five time constant in length, the capacitor will have sufficient time to charge and discharge when the pulse returns to 0 volts. Any increase in frequency beyond this will result in insufficient time for the charge/discharge cycle to complete. This frequency is the max frequency of input pulse that can be applied.

So min pulse width should be equal to **5RC** and form this max frequency can be calculated.

OBSERVATION AND CALCULATIONS

Table-1

No.	R	C	τ	5 τ	F
1	20KΩ	0.001µF			
2	10KΩ	0.001µF			

Charging of Capacitor

Table 2

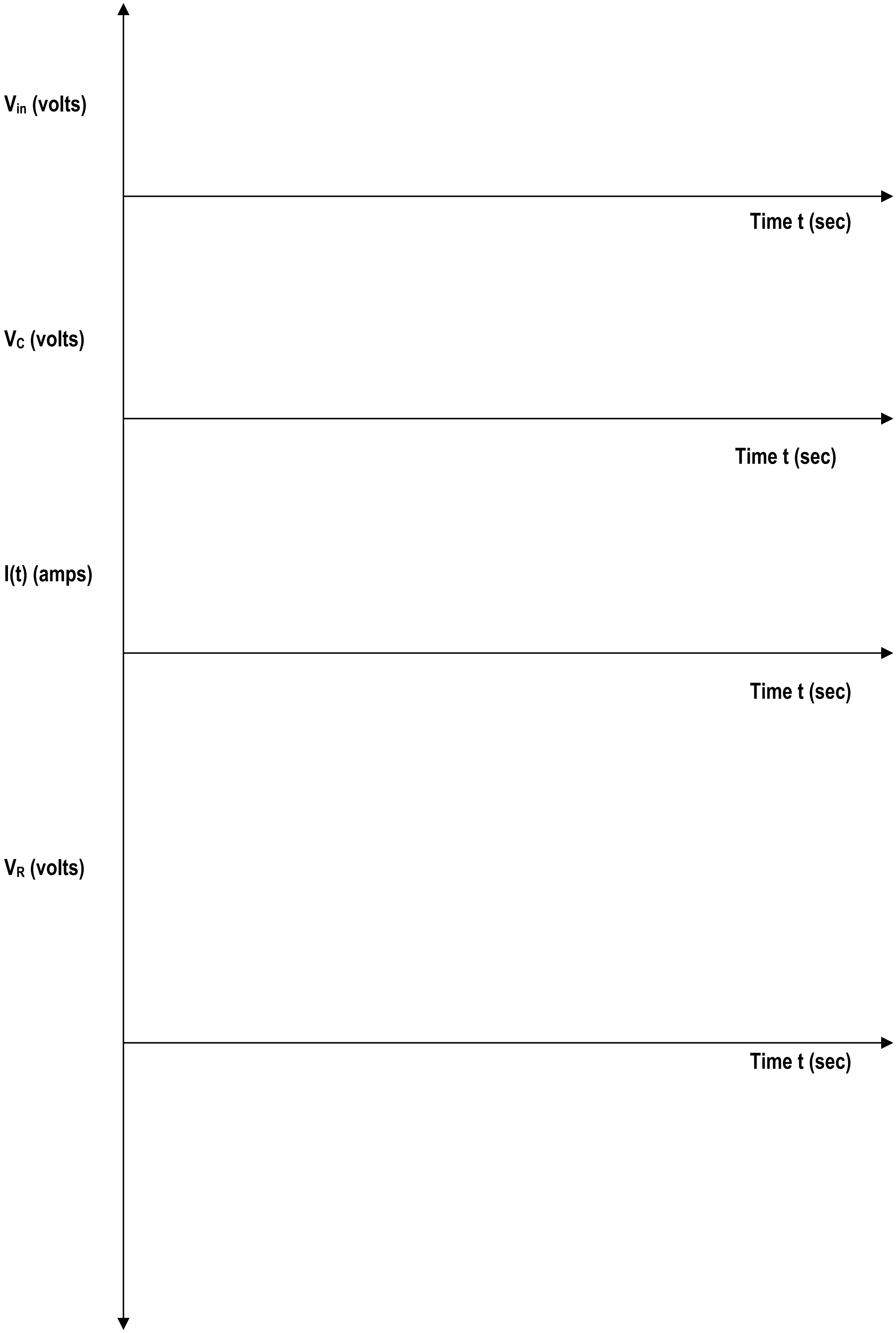
Number of Time Constant	Calculated Voltage Vc(volts)	Measured Voltage Vc(volts)
1τ		
2τ		
3τ		
4τ		
5τ		

Discharging of Capacitor

Table 3

Number of Time Constant	Calculated Voltage Vc(volts)	Measured Voltage Vc(volts)
1τ		
2τ		
3τ		
4τ		
5τ		

WAVEFORMS OF VOLTAGES& CURRENTS



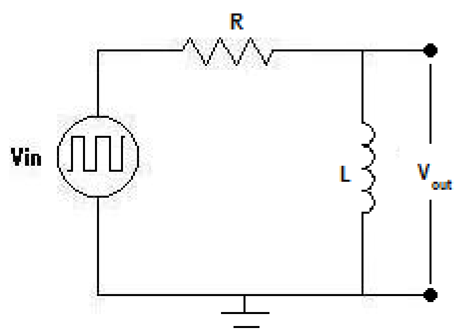
EXPERIMENT 09

TO STUDY THE PULSE RESPONSE OF A SERIES RL NETWORK

EQUIPMENT

1. Signal generator
2. Oscilloscope
3. Inductor:100mH
4. Resistor: 10KΩ /20KΩ

CIRCUIT DIAGRAM



THEORY

This lab is similar to the RC circuit lab except that an Inductor replaces the capacitor. In this experiment we apply a square waveform to the RL circuit to analyze the transient response of the circuit. The pulse –width relative to the circuit's time constant determines how it is affected by the RL circuit.

Rise of current

At the instant when step voltage is applied to an RL network, the current increases gradually and takes some time to reach the final value. The reason the current does not build up instantly to its final value is that as the current increases, the self-induced e.m.f in L opposes the change in current (Lenz's Law). Mathematically, it can be shown,

$$I(t) = V/R\ (1-e^{-t/\tau})$$

Where $t =$ time elapsed since pulse is appliad
$\tau =$ L/R= time constant of the circuit

(ii) Decay of the current

During the next half cycle of the pulse, when the pulse amplitude is zero, the current decreases to zero exponentially. Mathematically, it can be shown,

$$I(t) = V/R\ e^{-t/\tau}$$

PROCERURE

1. Set the output of the function generator to a square-wave with frequency 2 KHz and peak-to-peak amplitude 5V.
2. Wire the circuit on breadboard.
3. Display simultaneously voltage V_{in} (t) across the function generator (on CH 1) and V_L (t) across the inductor L (on CH 2).
4. Sketch the two measured waveform V_{in} (t) and V_L (t), calculate and sketch the waveform, V_R (t) and I(t), Label the time, voltage and current scales. Note that the voltage across resistor R, V_R (t), also represents the current I(t).
5. Measure the time constant, τ using the wave form V_R (t). Expand the time scale and measure the time it takes for the waveform to complete 63% of its total change, i.e. 5V. Enter the measured value of τ in Table.
6. Compare values of the theoretically expected and experimentally obtained time constants τ.

OBSERVATION AND CALCULATIONS

Table-1

No.	R	L	τ	5 τ	F_{MAX}
1	20KΩ	100 mH			
2	10KΩ	100 mH			

Rise of Current

Table 2

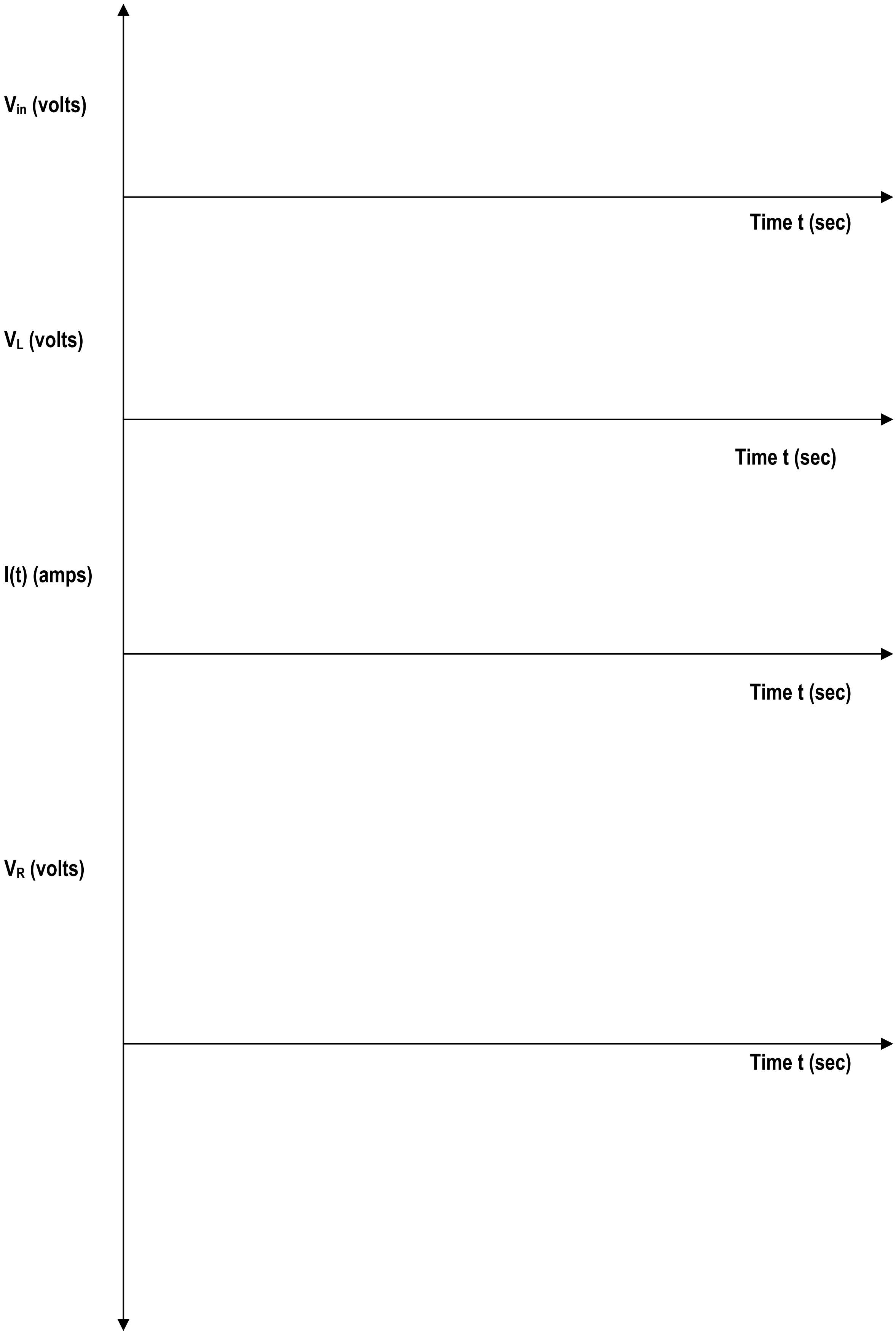
Number of Time Constant	Calculated Current (Amps)	Measured Current (Amps)
1τ		
2τ		
3τ		
4τ		
5τ		

Decay of Current

Table 3

Number of Time Constant	Calculated Current (Amps)	Measured Current (Amps)
1τ		
2τ		
3τ		
4τ		
5τ		

WAVEFORMS OF VOLTAGES& CURRENTS



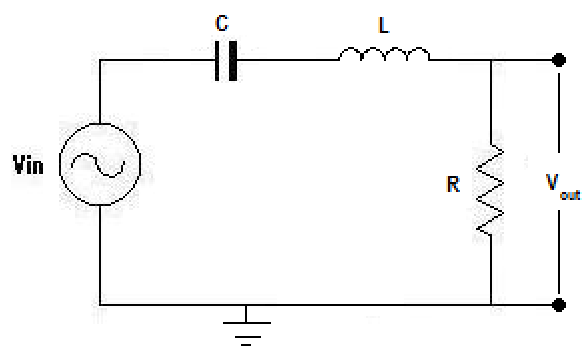
EXPERIMENT 10

TO SHOW THE FREQUENCY RESPONSE OF A SERIES RLC NETWORK AND SHOW THAT THE RESONANT FREQUENCY OF A SERIES RLC CIRCUIT IS GIVEN BY 1/2T√ LC.

EQUIPMENT

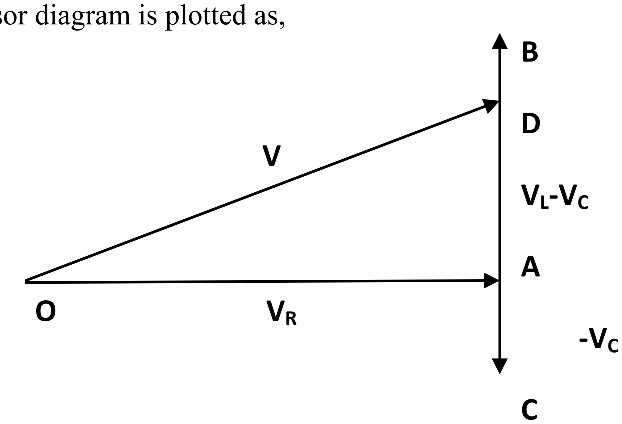
1. Signal Generator
2. Inductor: 100-200 mH
3. Capacitors: 0.001µF and 0.01µF
4. Resistor: 100Ω±5 percent
5. Oscilloscope
6. Multimeter

CIRCUIT DIAGRAM



THEORY

As shown in the circuit diagram, resistor, inductor and capacitor are connected in series with an a.c. supply of r.m.s. voltage V. The Phasor diagram is plotted as,



Let V_R = IR = voltage drop across R

$V_L = IX_L$ = voltage drop across L

$V_C = IX_C$ = voltage drop across C

In voltage triangle of fig 1, OA represents V_R, AB and AC represents the inductive and capacitive drop respectively. It will be seen that V_L and Vc are 180 degree out of phase with each other i.c. they are in direct opposition to each other.

Subtracting AC from AB, we get the net reactive drop AD = $I(X_L - X_C)$

The appliad voltage V is represented by OD and is the vector sum of OA and AD.

$OD = \sqrt{(OA^2 + AD^2)}$

$V = \sqrt{[(IR)^2 + (IX_L - IX_C)^2]} = I\sqrt{[(R)^2 + (X_L - X_C)^2]}$

$I = V/\sqrt{[(R)^2 + (X_L - X_C)^2]} = V/Z$

The term is known $[(R)^2 + (X_L - X_C)^2]$ as the impedance of the network. Obviously,

$$(\text{Impedance})^2 = (\text{Resistance})^2 + (\text{Net Reactance})^2$$

Resonance in RLC Networks

Resonance means to be in step with. When the appliad voltage and the current in an a.c. network are in step with i.e. phase angle between voltage and current is zero or pf = 1, the circuit is said to be in resonance.

An a.c. circuit containing reactive element (L and C) is said to be in resonance when the net reactance is zero.

When a series R-L-C is in resonance, it possesses minimum impedance Z = R. Hence, circuit current is maximum, it being limited by value of R alone. The current $I_o = V/R$ and is in phase with V. since circuit current is maximum, it produces large voltage drops across L and C. but these drops being equal and opposite, cancel out each other. Taken together, L and C from part of a circuit across which no voltage develops however, large the current flowing. If it were for the presence of R, such a resonant circuit would act like a short circuit to currents of the frequency to which it is often referred to as voltage resonance.

The frequency at which the net reactance of the series circuit is zero is called the resonant frequency. Its value can be found as found as under:

$X_L - X_C = 0$

$X_L = X_C$ or $\omega_o L = 1/\omega_o C$

$\omega_o^2 = 1/LC$ or $(2\pi f_o)^2 = 1/LC$ or $f_o = 1/2\pi\sqrt{LC}$

If L is in Henry and C is in Farad, then f_o is in Hertz

PROCEDURE

1. For the given inductor and capacitor calculate the resonant frequency and connect the circuit as shown in circuit diagram
2. Apply sinusoidal signal from the generator of the 5V pk to the network and set the frequency to a value of 500 Hz
3. Observe V_R, V_L and V_C on the oscilloscope and record it.
4. Increase the frequency of the signal and for each frequency measure and record V, V_R, V_L and V_C and maintain applied voltage constant at $5V_P$
5. Now measure V_R, V_L and V_C theoretically and compare the results.

OBSERVATIONS &CALCULATIONS

$$V_{rms} = V_P/\sqrt{2}$$

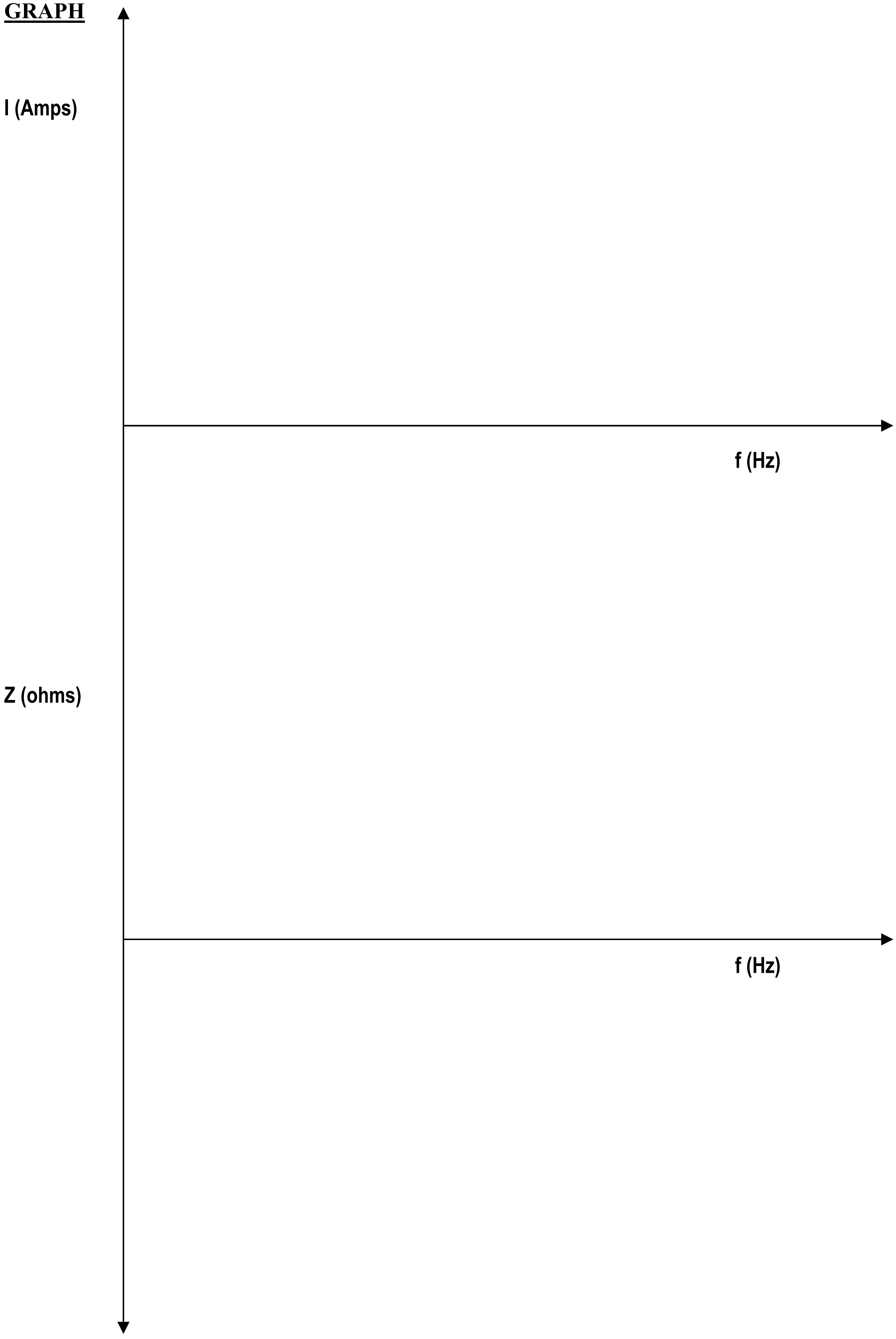
Calculated value

No.	Frequency f (Hz)	X_L (ohms)	X_C (ohms)	Z (ohms)	$I=V_R/R$ (Amps)	$V_L=IX_L$ (Volts)	$V_C=IX_C$ (Volts)
1							
2							
3							
4							
5							

Measured Values

No.	Frequency f (Hz)	X_L (ohms)	X_C (ohms)	Z (ohms)	$I=V_R/R$ (Amps)	$V_L=IX_L$ (Volts)	$V_C=IX_C$ (Volts)
1							
2							
3							
4							
5							

GRAPH



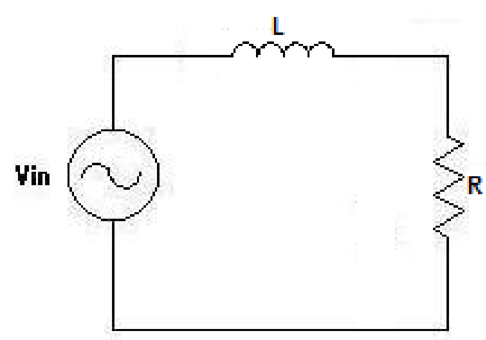
EXPERIMENT 11(a)

TO STUDY THE SINUSOIDAL RESPONSE OF RL CIRCUIT

APPARATUS

1. Signal generator
2. Oscilloscope
3. Multimeter
4. Inductor 100 mH
5. Resistor 2K

CIRCUIT DIAGRAM



THEORY

Circuit containing inductance and resistance appear in variety of electronic circuits, from power supplies to filters. In this experiment we are going to investigate the sinusoidal response of a series RL circuit. A difficulty arises in conjunction with such circuit in that real conductor are not like ideal conductor we deal in our theory. Since they are formed of coiled wire, they possess resistance as will as inductance. Furthermore their resistance is dependent on frequency as will. As a consequence, the inserted R does not represent the total resistance of the circuit. In addition, when we measure the voltage across a coil, we are getting both inductive and resistive component of voltage, not simply VL. In this experiment, we will try to overcome this problem by making R large compared with the ac resistance of coil, that is we will presume the coil is ideal.

Relation for steady state ac analysis are as follows

$Z_L = j2\pi fL$

$Z_{TOTAL} = R + Z_L$

$I = V_{in} / Z_{TOTAL}$

$V_R = IR$

$V_L = IZ_L$

PROCEDURE

1. Calculate and note down quantities Z_L, Z_{TOTAL}, I, V_R and V_L for a source voltage of 5V peak and frequency 1 KHz. Remember to use $V_{rms} = V_P/\sqrt{2}$ in calculations.
2. Connect the circuit as shown in diagram and adjust the function generator voltage and frequency to the values chosen above.
3. Use Multimeter to measure voltages V_L and V_R and note down in Table.
4. Compare measured and calculated values.
5. Explain any discrepancies between measured and calculated values of V_R and V_L.
6. Draw a phasor diagram of the calculated voltages in diagram. Include I as a reference phasor and show the position of V_R and V_L.

OBSERVATONS AND CALULATIONS

Table 1

CALCULATION PARAMETERS				
Z_L	Z_{TOTAL}	I	V_R	V_L

Table 2

MEASURED		I= V_R/R	Z_L =V_L/I	Z=Vi/I
V_R	V_L			

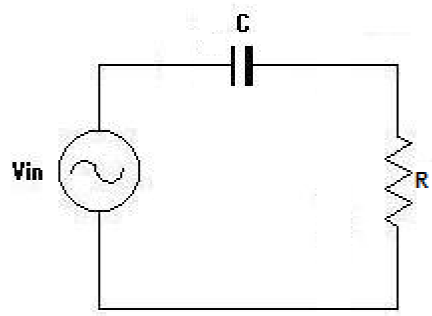
EXPERIMENT 11(b)

TO STUDY THE SINUSOIDAL RESPONSE OF RC CIRCUIT

APPARATUS

1. Signal generator
2. Oscilloscope
3. Capacitor 0.1µF
4. Resistor 2K

CIRCUIT DIAGRAM



PROCEDURE

(Similar to the above part, except a capacitor replaces inductor)

1. Calculate and note down quantities Z_C, Z_{TOTAL}, V_R and V_C for a source voltage of 5V peak and frequency 1 KHz. Remember to use $V_{rms} = Vp/\sqrt{2}$ in calculations
2. Connect the circuit as shown in diagram and adjust the function generator voltage and frequency to the values chosen above.
3. Use Multimeter to measure voltages V_C and V_R and note down in Table.
4. Compare measured and calculated values.
5. Explain any discrepancies between measured and calculated values of V_R and V_C.
6. Draw a phasor diagram of the calculated voltages in diagram. Include I as a reference phasor and show the positions of **Vi**, V_R and V_C .

OBSERVATIONS AND CALCULATIONS

Table 1

Calculation Parameters				
Z_C	Z_{TOTAL}	I	V_R	V_C

Table 2

Measured		$I = V_R/R$	$Z_C = V_C/I$	$Z = Vi/I$
V_R	V_C			