UOWD

University of Wollongong in Dubai

Student Names and ID's : 1

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Laboratory session 7 Week 8

Objective: Working with LC and RLC Circuits

Instructors:

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Part A Understanding Faraday's Law

1) Faraday's Law emf Induction

   http://www.youtube.com/watch?v=vwIdZjjd8fo
   http://www.youtube.com/watch?v=KGTZPTnZBFE

2) Making a motor

   http://www.youtube.com/watch?v=WKklyuzghQg

3) Current generator
   http://www.youtube.com/watch?v=gfJG4M4wi1o

Part B

RL Circuit

When a DC voltage is applied to an inductance and a resistor in series (a Series RL circuit) a steady current will be established:

$$I_{max} = \frac{V_0}{R} \tag{1}$$

where V_0 is the applied voltage and R is the total resistance in the circuit. But it takes time to establish this steady-state current because the inductor a back emf in response to the rise in the current. The current will rise exponentially derived from solving the differential equation (5):

$$I(t) = I_{max}\,(1 - e^{-(R/L)t}) = I_{max}\,(1 - e^{-\frac{t}{\tau}}) \tag{2}$$

Where L is the inductance and $L/R=\tau$ is the inductive time constant. Note the time to reach half maximum is related to inductive time constant by:

$$\tau = \frac{t_{1/2}}{\ln(2)} \tag{3}$$

The voltage across the inductor is proportional to the time rate of change:

$$V_L(t) = L\frac{dI}{dt} = L\ I_{max}\,(e^{-t/\tau})/_{\tau} \quad = \quad R\ I_{max}\,(e^{-t/\tau}) \tag{4}$$

Kirchoff's law, that states that the voltage changes around a circuit loop is zero is written as:

$$V_L + V_R = V_0 = L\frac{dI}{dt} + RI \tag{5}$$

From eq. 4, the voltage across the resistor is given by

$$V_R = V_0 - V_L = V_0(1 - e^{-t/\tau}) \tag{6}$$

Eq 4 and 5, shows that as the current exponentially builds up, the voltage across the resistor increases and the voltage across the inductor decreases (note that the derivation is based on the assumption that there is no internal resistance by the inductor.

When a DC voltage is turned off

$$IR + L\frac{dI}{dt} = 0 =>$$

$$I = I_{max} e^{-t/\tau} \tag{7}$$

$$V_R = V_0 e^{-t/\tau} V_L = \quad .$$

The potential difference across the inductor is negative because the inductor acts like a battery

$$V_L = -Ve^{-t/\tau} \tag{8}$$

Part C: Experimenting with RL circuit

1) First in order to calibrate the use of the oscilloscope and the function generator (specifiable voltage applied over a specifiable time), set the function generator to produce a square wave (of about 1000 Hz frequency and about 5 volts amplitude). You should be able to read from the oscilloscope both the period and the voltage. You may record TIME/DIV=________
VOLTS/DIV=________

2) Hook up an RL circuit with R= about 300 Ω (you may use the resistance box) and L = about 300 mH.

3) Connect channel 1 of the oscilloscope to measure voltage through the resistance and connect channel 2 of oscilloscope to measure voltage through the inductor.

4) Use a square wave to "turn on and off" the RLC circuit. The square wave produces the same effect as a battery being switched on and off periodically.

5) Construct the circuit below. Route the square wave to the input of the circuit. Direct the output from the resistor to channel 1 and the output from the inductor to channel 2 (of the oscilloscope).

6) The frequency of the input signal should be selected such:

$$\frac{1}{f_{signal}} = T >> \tau = L / R$$

This allows for the observation of fully charging and discharging process

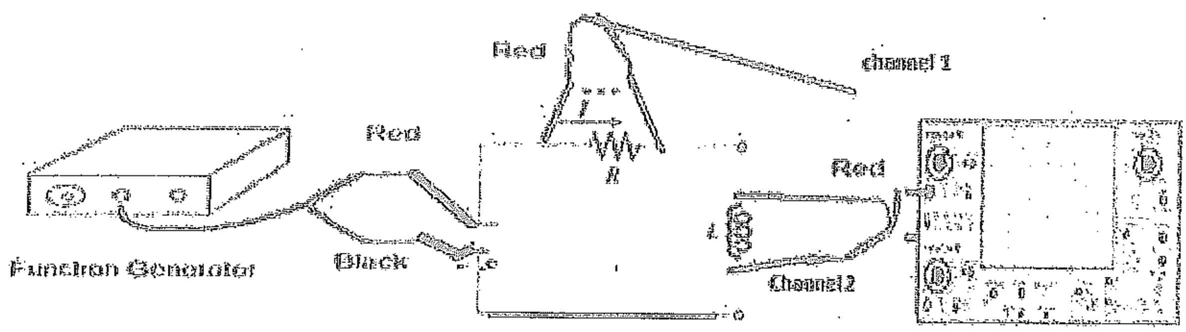

Figure 1. RL circuit

7) Fill the table below experiment with different inductors and resistors

	R	L	τ (theoretical)	Input Voltage Vmax	Frequency in Hz	T in sec	τ Oscilloscope use eq. 3	Maximum Voltage across resistance VR	Maximum Voltage across inductor	$V_{max}-V_R$	$V_{max}-V_L$
Experiment 1											
Experiment 2											

Record both voltages of the resistor $V_R(t=\tau)$ and the voltage of the inductor V_L $(t=\tau)$ and compare their sum to V_{max}.

8) Plot V_L and V_R from the oscilloscope while the inductor is charging.

9) Plot V_L and V_R from the oscilloscope while the inductor is discharging.

Part D Experimenting with a RLC circuit (DC voltage)

Purpose:

- Understand RLC circuit resonance.
- Observe **underdamped** and overdamped oscillations in RLC circuits

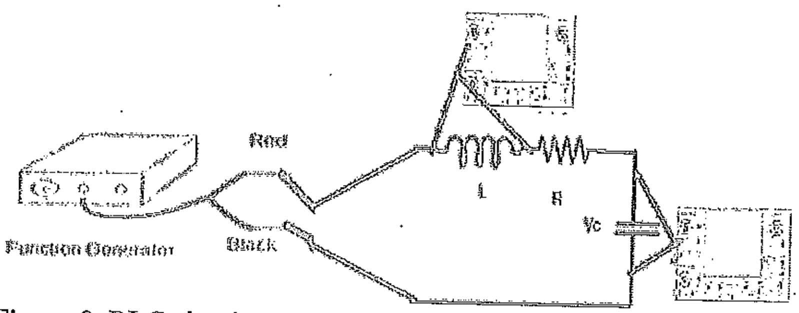

Figure 2. RLC circuit

Assuming the capacitance has been fully charged with a charge Q_{max}.

Similarly the above equation is given by

$$V_L + V_R + V_C = 0$$

$$L\frac{dI}{dt} + RI + \frac{Q}{C} = 0$$

$$L\frac{d^2Q}{dt} + R\frac{dQ}{dt} + \frac{Q}{C} = 0$$

The solution of this equation describes the response of the circuit:

When R is very small such that $R < 2\sqrt{L/C}$

the solution to the above differential equation is given by

$$Q = Q_{max}e^{-\frac{Rt}{2L}}\cos(\omega t)$$

Where $\omega = \left[\frac{1}{LC} - \left(\frac{R}{2L}\right)^2\right]^{1/2}$

Therefore both the current and the voltage through the capacitance oscillates (with damping) as a function of time. When the resistor is larger than the critical value the system is overdamped. The charge actually takes longer to return to zero than in the critically damped case.

Conducting the experiment

The decaying oscillations in the LRC circuit can be observed using the same technique as used to observe exponential decay. Again, a square-wave generator produces the same effect as a battery switched on and off periodically. The oscilloscope measures the voltage across the *capacitance* as a function of time.

In this experiment you need to examine the behaviour of such an oscillation of the circuit as shown in figure 2. Plot the oscillations and report R (use small R), L, Capacitance, maximum charge used. You may investigate further with larger resistance.