Purposes
Get familiar with the usage of an oscilloscope and a function generator. Understand how a
digital multimeter works with AC signal. Show that the current flowing in a capacitor is
proportional to the time derivative of the voltage across the capacitor.

1 Time domain study of oscillations

Build the circuit shown in Figure 1 with \( L = 1 \text{ mH} \). Setup the signal generator to provide square
signals with proper amplitude and frequency to clearly see the signal oscillation due to the RLC
circuit: tune \( f \) closed to the resonance frequency.

![Figure 1: Circuit for parts 1 and 2.](image)

1. Take \( C = 100 \text{ nF} \) a vary \( R \) from 0 to 5 k\( \Omega \), observe, i.e. make a sketch and describe, the
different oscillatory regimes. For \( R = 0 \), the oscillation are still damped why?

2. For \( R = 0 \), measure the oscillation period, \( T_0 \), for \( C = 11, 27, 51.1, 100, 220, 470 \text{ nF} \). Plot
\( \omega_0 \equiv 2\pi/T \) versus \( C \) and superimpose the theoretically expected curve.

3. For each of the previously use capacitor value, vary \( R \) and find out the critical resistance
(corresponding to the critical damping regime). Plot \( R \) versus \( C \) and superimpose the
theoretically expected curve.

4. For the case \( C = 100 \text{ nF} \) measure the amplitudes of consecutive oscillation maxima \( U_n, U_{n+1} \) (see Figure 2) and using the formula \( \delta = 1/T_0 \log[U_n/U_{n+1}] \) compute the damping
constant \( \delta \).
2 Resonance

Consider the same circuit as built in the previous section but setup the signal generator to produce a sinusoidal wave. Use a capacitor with capacitance $C = 11 \text{nF}$.

1. For different values of $R$ approximately corresponding to quality factor of $Q = 0.1, 1, 2$, and 5:

   (a) vary the frequency of the sinusoidal signal,
   (b) for each frequency setting, measure the voltage across the capacitor $V_c$ and the tension produced by the frequency generator $V_g$ (the oscilloscope will be used in "standard" mode),
   (c) compute the ratio $T(f) \equiv V_c/V_g$,
   (d) switch the oscilloscope to X-Y mode you should see an ellipse,
   (e) measure the phase between the two signal $\Phi(f)$ (see section 3).

2. For the four cases of resistance values, corresponding to $Q = 0.1, 1, 2$, and 5, plot the curves $T(\omega)$ and $\Phi(\omega)$ as a function of $\omega/\omega_0$ [$\omega_0$ is the resonance frequency of the circuit that you can compute knowing $L$ and $C$].
3. Superimpose with the theoretical curve for $T(\omega)$.

3  Lissajou’s technique to measure the phase between two sinusoidal signals

Let consider two sinusoidal voltages $V_1 = A \sin(\omega t)$ and $V_2 = B \sin(\omega t + \phi)$. $V_1$ and $V_2$ are respectively applied to X- and Y- channel of the oscilloscope. The oscilloscope, when operated in X-Y mode, displays an ellipse; see Figure 3. When $X = 0$, $A \sin(\omega t) = 0$ so $B \sin \Phi = [OB']$.

![Figure 3: Illustration of Lissajou’s technique.](image)

The distance $[OB]$ is $B$, the signal amplitude. Thus $\sin \Phi = \frac{[OB']}{[OB]}$. Similarly one can show that we also have $\sin \Phi = \frac{[BC']}{[BC]}$. For this technique to be accurate you should first make sure when no voltage is apply to channels X and Y that the spot is well centered on the screen. Finally is the ellipse is such that its main axis as a negative slope then the phase is $\pi - \Phi$ where $\Phi$ is defined by either of the aforementioned equation.