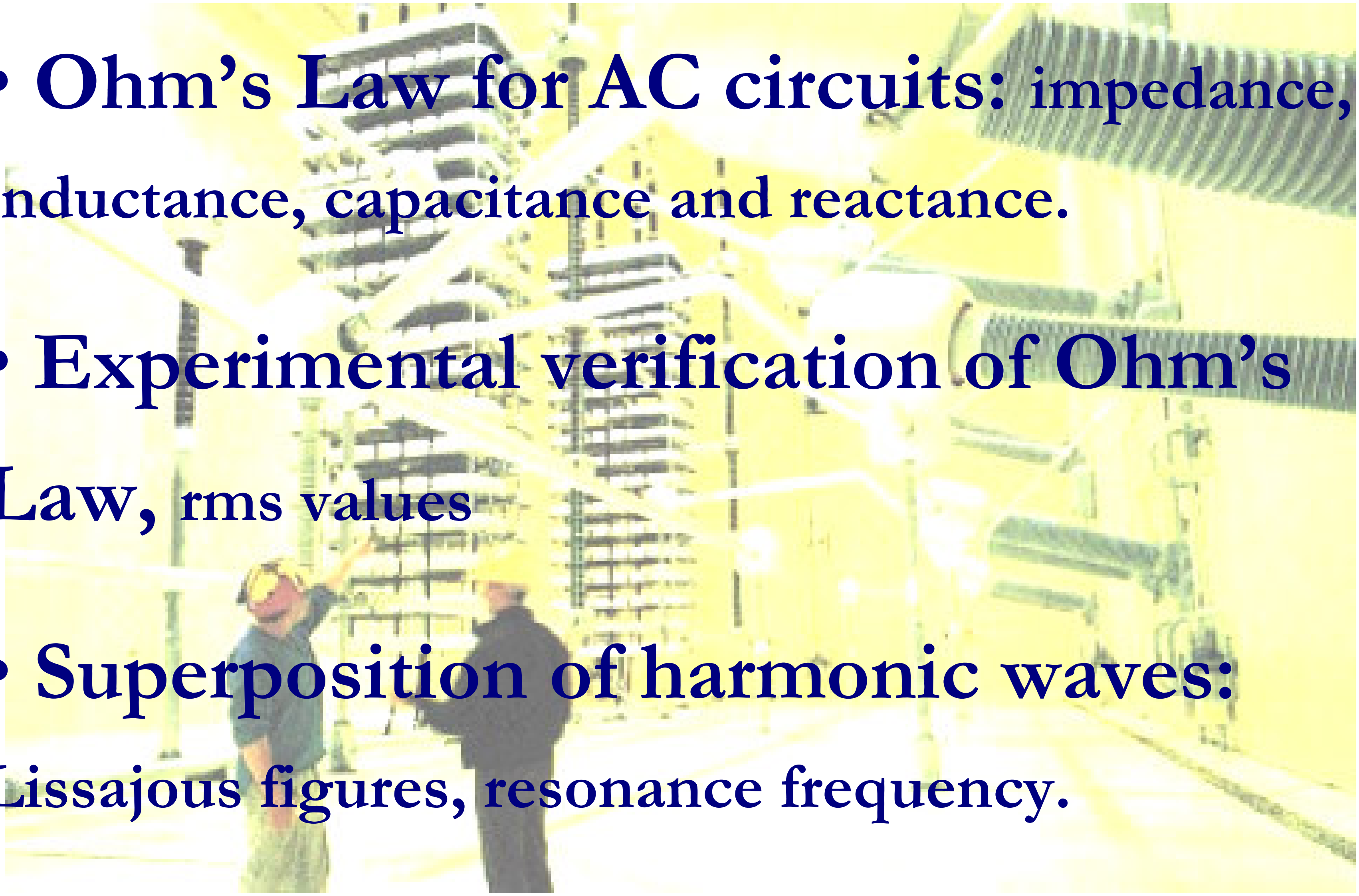
UNIVERSITAT JAUME•I

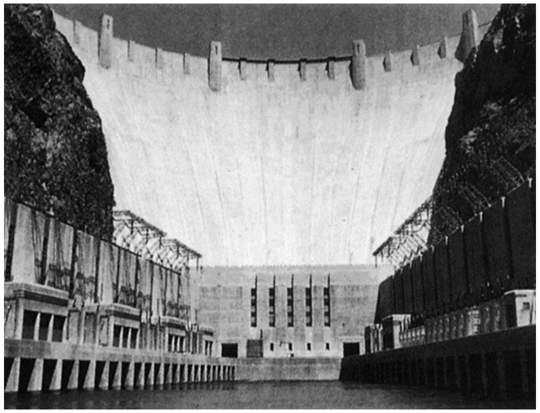
303 – Physics for Engineers II - Laboratory

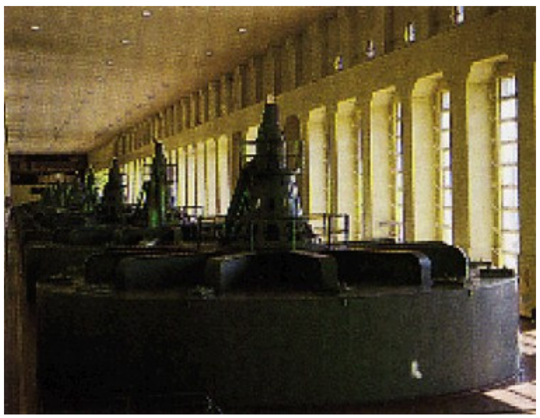
Experiment # 5: AC Measurements. Phase-angle measurement



- **Ohm’s Law for AC circuits:** impedance, inductance, capacitance and reactance.
- **Experimental verification of Ohm’s Law,** rms values
- **Superposition of harmonic waves:** Lissajous figures, resonance frequency.

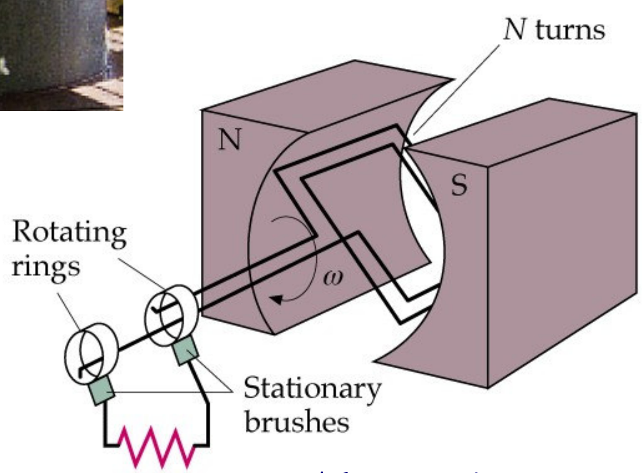
Alternating current generation

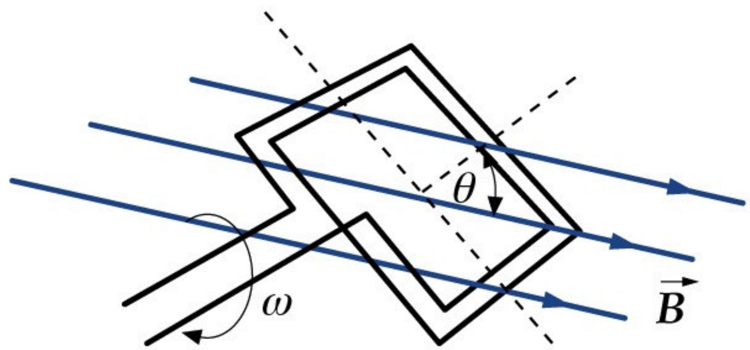




Faraday's law of induction: the induced emf in a circuit due to a changing magnetic flux is equal to the rate of change of the magnetic flux through the circuit

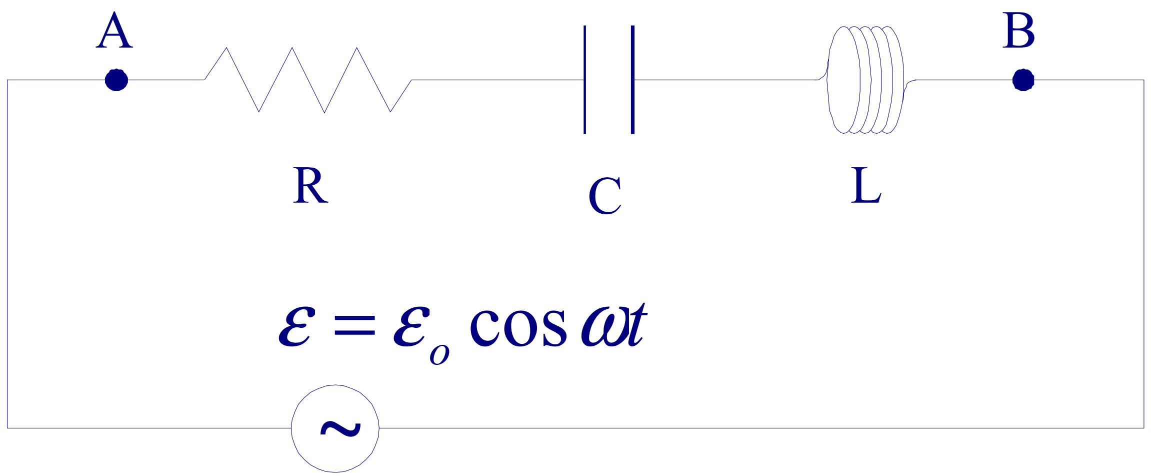
$$\varepsilon = -\frac{d\phi_m}{dt}$$





Alternating-current generator, alternator

AC Ohm's Law



$$\varepsilon = \varepsilon_o \cos \omega t$$

$$V_{AB} = IR + L\frac{dI}{dt} + \frac{q}{C} = \varepsilon_o \cos \omega t$$

$$\varepsilon(t) = IR + L\frac{dI}{dt} + \frac{1}{C}\int I dt$$

$$\frac{d\varepsilon(t)}{dt} = R\frac{dI(t)}{dt} + L\frac{d^2 I(t)}{dt^2} + \frac{I(t)}{C}$$

$$\varepsilon(t) = \varepsilon_o e^{j\omega t}$$

Stationary solution of the differential equation $I(t) = I_o e^{j\omega t}$

Impedance

$$I(t) = I_o e^{j\omega t}$$

We apply this solution to the original equation:

$$\varepsilon(t) = IR + L\frac{dI}{dt} + \frac{1}{C}\int I dt$$

$$\varepsilon(t) = I(t)\left[R + j\left(L\omega - \frac{1}{C\omega}\right)\right]$$

$$\varepsilon(t) = I(t)Z \quad \text{with} \quad Z = R + j\left(L\omega - \frac{1}{C\omega}\right)$$

impedance

inductance, X_L

capacitance, X_C

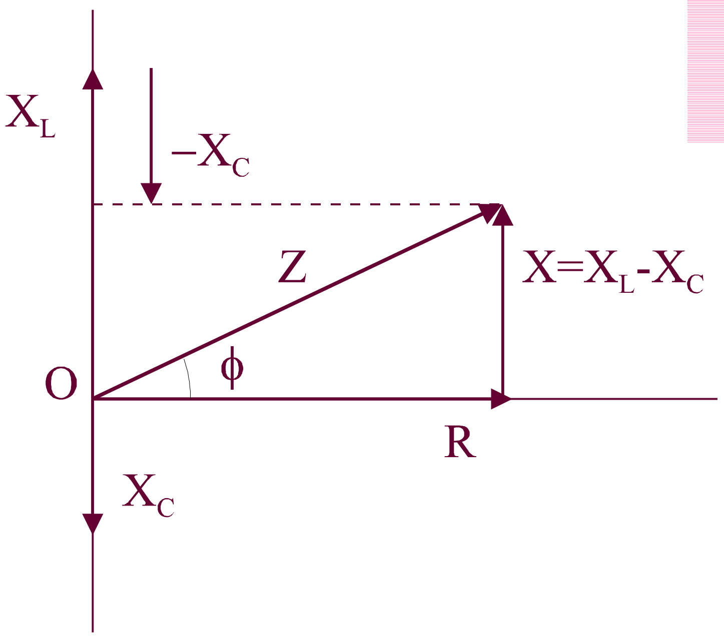
Impedance

$$Z = R + j\left(L\omega - \frac{1}{C\omega}\right)$$

$$Z = |Z|\, e^{j\phi}$$

$$|Z| = \sqrt{R^2 + \left(L\omega - \frac{1}{C\omega}\right)^2}$$

$$tg\phi = \frac{L\omega - \frac{1}{C\omega}}{R}$$



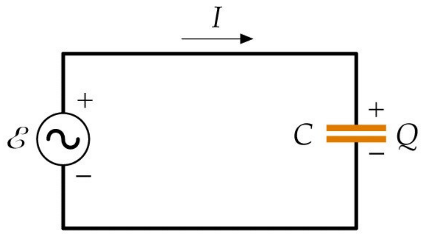
ϕ, angle between ε and I:

$$\varepsilon = \varepsilon_0 \cos \omega t$$

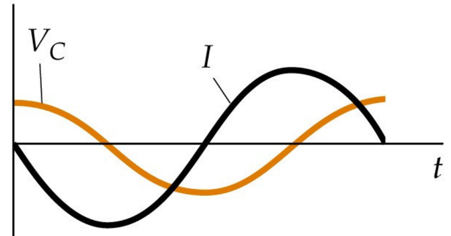
$$I = I_0 \cos(\omega t - \phi)$$

$$I_0 = \frac{\varepsilon_0}{|Z|}$$

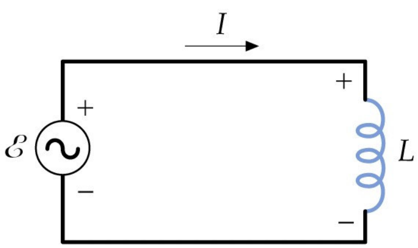
Phase-angle: phasor diagrams



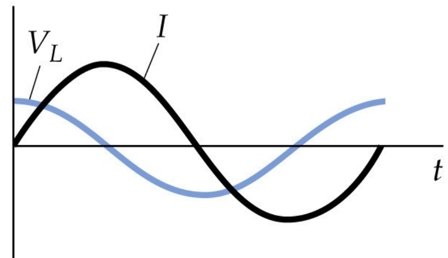
$$V_C(t) = V_{C,0}\cos(\omega t - \phi - \frac{\pi}{2})$$



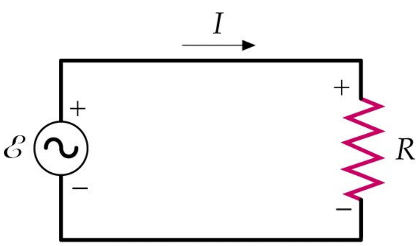
V retardat respecte a I



$$V_L(t) = V_{L,0}\cos(\omega t - \phi + \frac{\pi}{2})$$

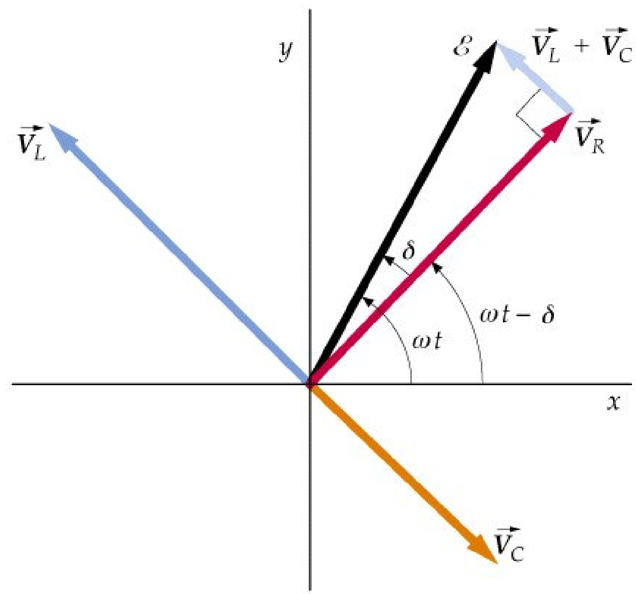


V avançat respecte a I



$$V_R(t) = V_{R,0}\cos(\omega t - \phi)$$

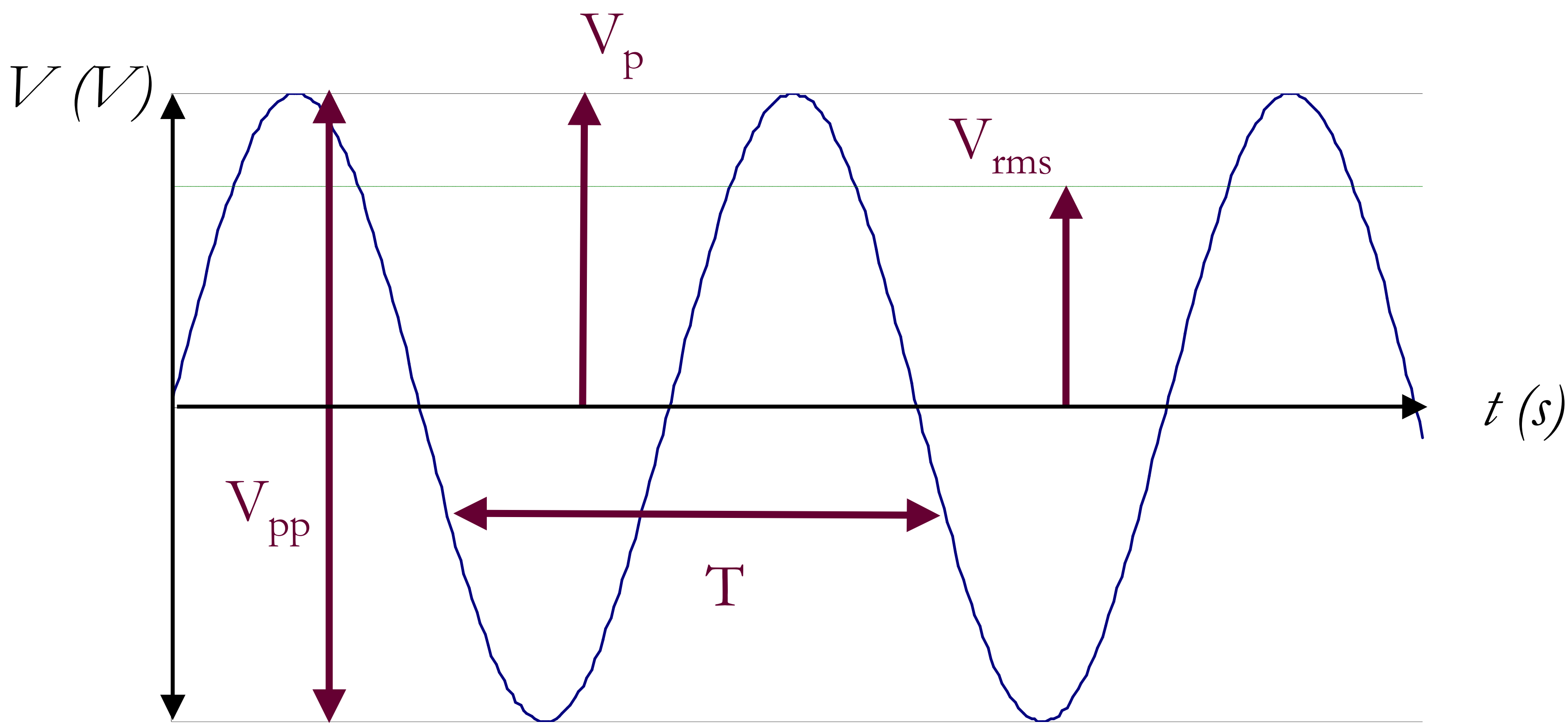
$$V_T(t) = V_{T,0}\cos\omega t$$



Recall: rms Voltage

When dealing with AC circuits, the root mean square values (rms) describe the general time average behaviour of the sinusoidally varying quantities (voltage, current, etc.).

The average thermal power generated in a resistor calculated with rms values equals the steady current result.

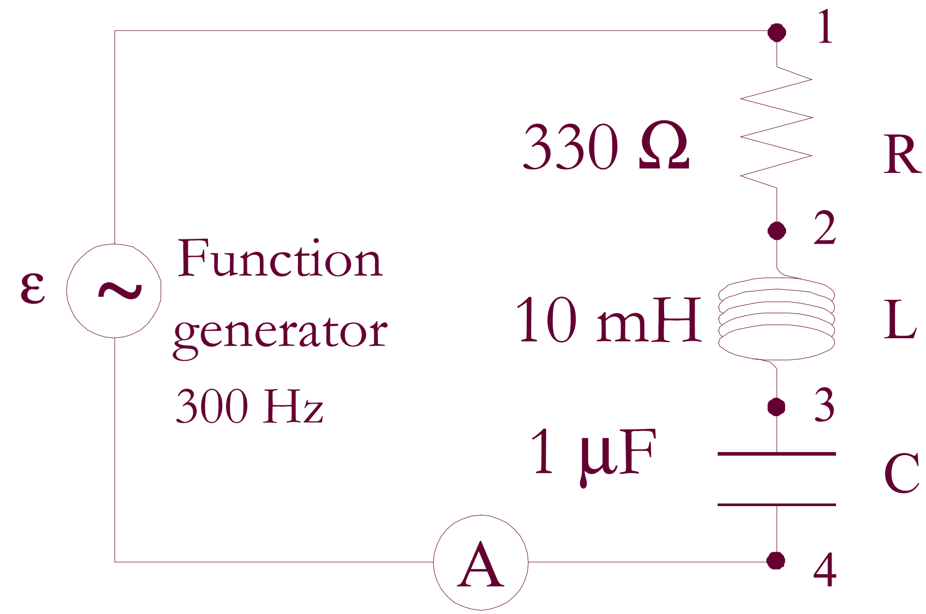


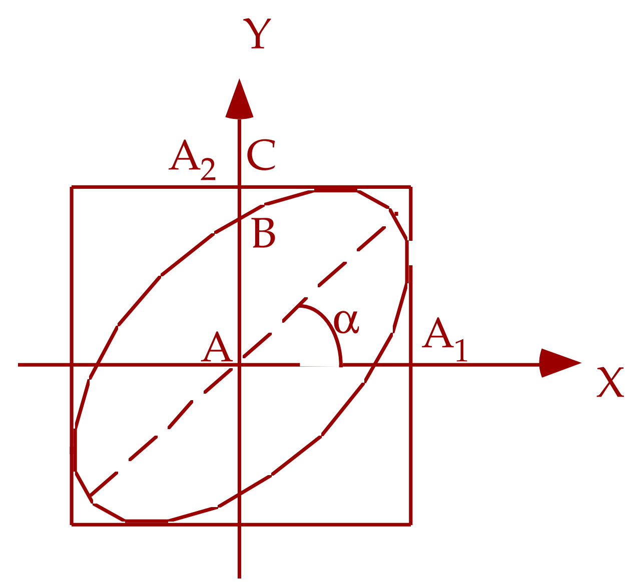
$$T = \frac{1}{\nu} = \frac{2\pi}{\omega} \qquad V_{rms} = \sqrt{avg\left(V^2\right)}$$

for a sinusoidal signal: $V_{rms} = \frac{V_p}{\sqrt{2}} = \frac{V_{pp}}{2\sqrt{2}}$

Experimental procedure

1. Determine the resistance of inductor and resistor.
2. Circuit arrangement and verification of Ohm's Law for every element in circuit: determination of R, L, C, |Z|.
3. Direct observation of V_T and V_R, phase-angle measurement
4. Phase-angle measurement from Lissajous figures.
5. Resonant frequency determination.
6. Questions





Questions

1.- What is the difference between multimeter and oscilloscope voltage measurements?

2.- What would happen to Lissajous figures with different frequency signals in channels 1 and 2?

3.- Justify equation (19) in the lab guide. Is it still valid for signals of different frequency?

4.- Obtain equation (23) from equation (21) and figure 5.

5.- Show that intensity through the circuit is maximum at resonance.