Inducción electromagnética

F II

Ley de Faraday. Campo eléctrico inducido

Fuerza electromotriz de movimiento

Autoinducción e inducción mútua

Energía magnética.

Circuitos L-R, L-C y L-C-R

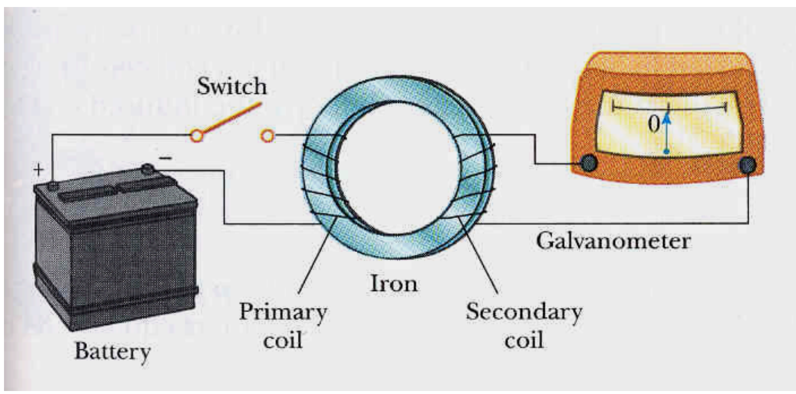
Corriente de desplazamiento

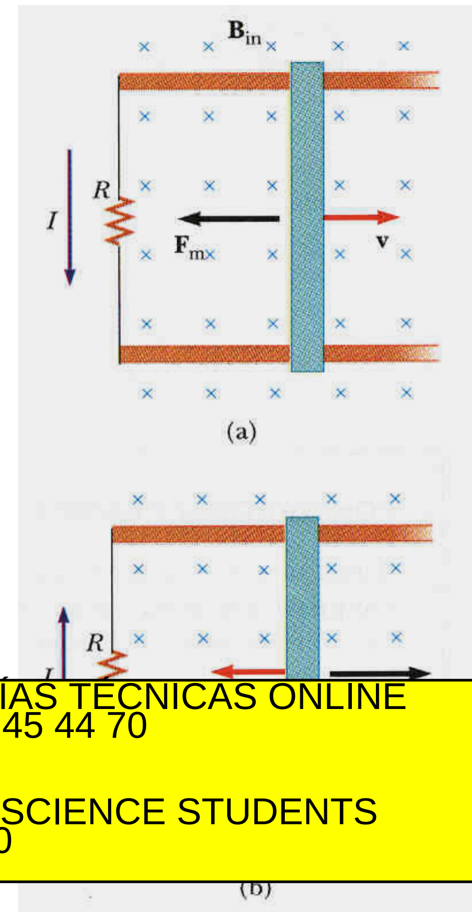
Ecuaciones de Maxwell

Inducción electromagnética

Experimentos de inducción

F II





Ley de Faraday

F II

Circuito de área A, rígido o deformable

Campo B, variable con el tiempo o uniforme

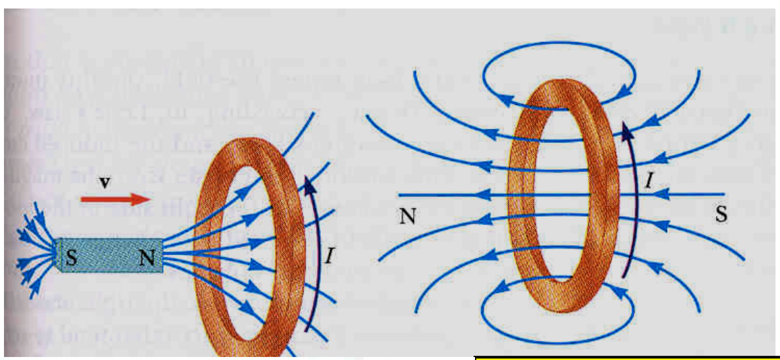
Flujo magnético $$\Phi_B = \Phi_B(t) = \int_A \mathbf{B} \cdot \mathbf{n}\, da$$

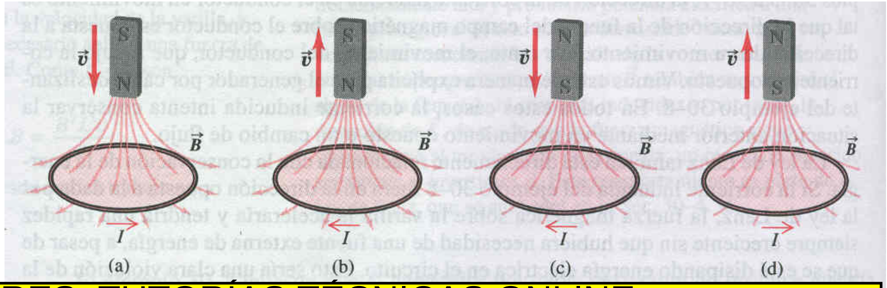
Ley de Lenz

F II

Significado del signo en ley de Faraday

Oposición a la variación del flujo





Campo eléctrico inducido

Campo magnético variable con el tiempo

F II

Campo eléctrico inducido sin circuito

$$\mathcal{E} = \int_C \mathbf{E}\cdot d\mathbf{l} = -\frac{d}{dt}\int_A \mathbf{B}\cdot\mathbf{n}\, da$$

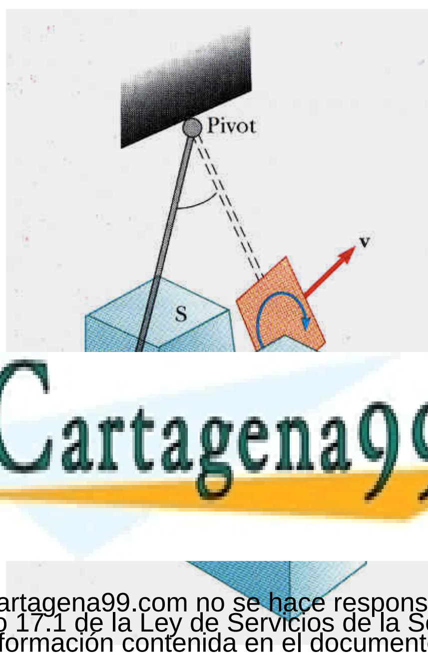
$$2\pi r E = -\frac{d}{dt}\left(B(t)\pi r^2\right) \quad E = \ldots \frac{r}{\ldots}\frac{dB}{\ldots}$$

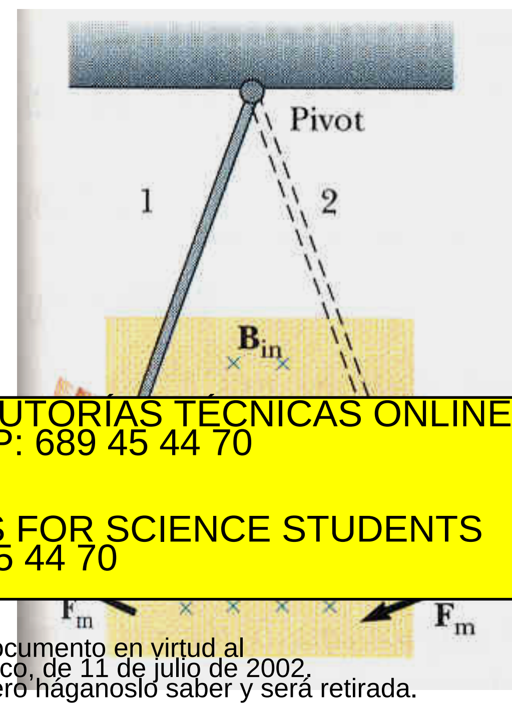
Corrientes parásitas

F II

Campo magnético variable con el tiempo

Corriente inducida en conductores

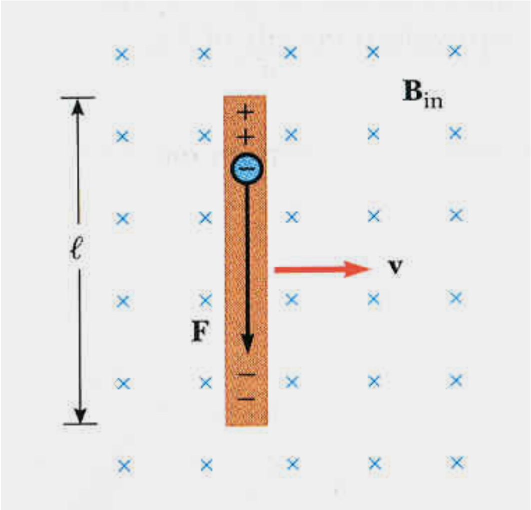


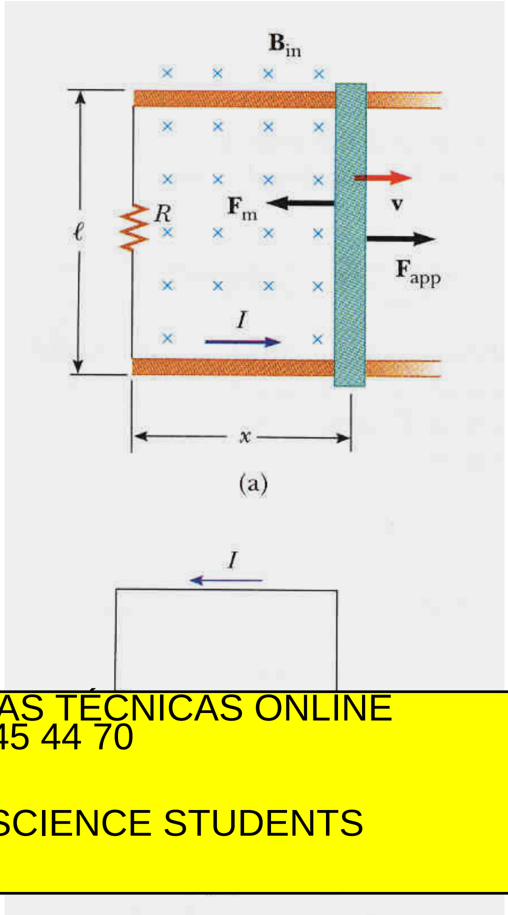


Fuerza electromotriz de movimiento

F II

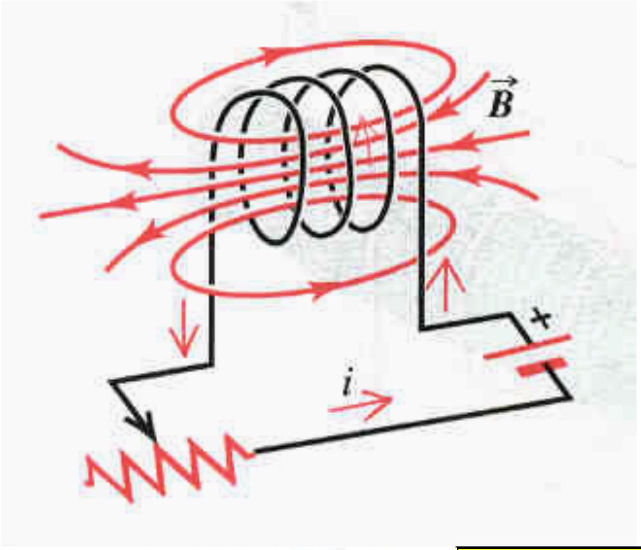
$$\mathcal{E} = -\frac{d}{dt}\left(BLx(t)\right) = BLv$$





Autoinducción

F II

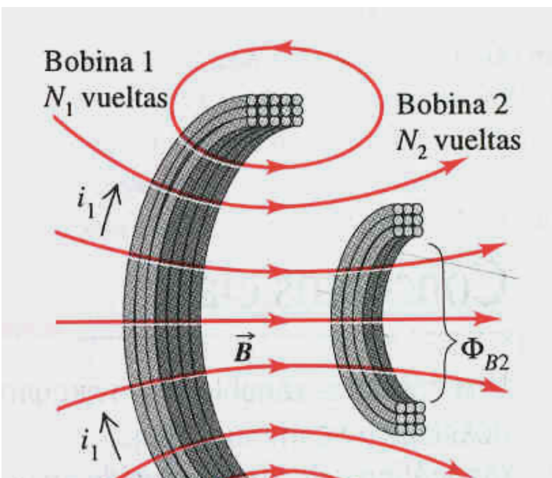


$$L = \frac{N\Phi_B}{i};\ N\frac{d\Phi_B}{dt} = L\frac{di}{dt};\ \mathcal{E} = -L\frac{di}{dt}$$

Inducción mutua

F II

$$\mathcal{E}_2 = -N_2 \frac{d\Phi_{B2}}{dt};\ N_2\Phi_{B2} = M_{21} i_1;\ \mathcal{E}_2 = -M_{21}\frac{di_1}{dt}$$



$$\mathcal{E}_1 = -N_1 \frac{d\Phi_{B1}}{dt};\ N_1\Phi_{B1} = M_{12} i_2;\ \mathcal{E}_1 = -M_{12}\frac{di_2}{dt}$$

$$M_{12} = M_{21} = M = \frac{N_2\Phi_{B2}}{\ } = \frac{N_1\Phi_{B1}}{\ }$$

Cálculo inductancias

F II

$$B = \mu_0 \frac{N}{l} I, \ \Phi = \mu_0 \frac{N^2 A}{l} I; \ L = \mu_0 \frac{N^2 A}{l}$$

$$2\pi R B_1 = \mu_0 N_1 I_1; \ 2\pi R B_2 = \mu_0 N_2 I_2;$$

$$B_1 = \frac{\mu_0 N_1 I_1}{2\pi R}; \ B_2 = \frac{\mu_0 N_2 I_2}{2\pi R};$$

$$\Phi_{1,2} = \frac{\mu_0 N_1 N_2 A I_2}{2\pi R}; \ \Phi_{2,1} = \frac{\mu_0 N_2 N_1 A I_1}{2\pi R};$$

Energía magnética

F II

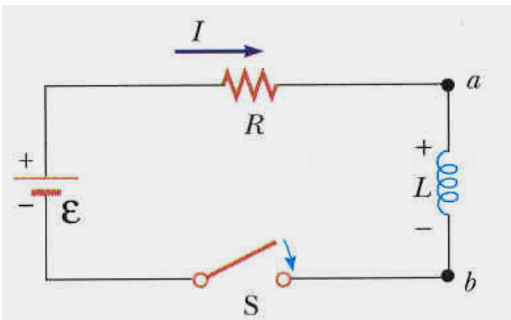
$$P(t) = -\mathcal{E} i(t) = Li\frac{di}{dt};\ U = \int_0^t Pdt = \int_0^I Lidi = \frac{1}{2}LI^2$$

Energía localizada en la corriente

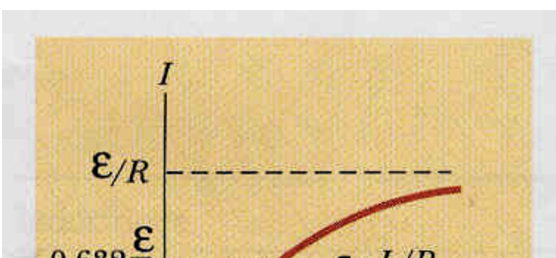
$$U = \frac{1}{2}\mu_0 \frac{N^2 A}{l} I^2 = \frac{1}{2}\left(\mu_0 \frac{N}{l} I\right)^2 \left(\frac{lA}{\mu_0}\right) = \frac{1}{2}\frac{B^2}{\mu_0} lA$$

Circuito R-L

F II



$$\mathcal{E} - L\frac{di}{dt} = Ri;\; i = \frac{\mathcal{E}}{R}\left(1 - e^{-\frac{R}{L}t}\right);\; \tau = \frac{L}{R}$$



$$Ri + L\frac{di}{dt} = 0;\; i = \frac{\mathcal{E}}{R}\left(e^{-\frac{R}{L}t}\right) = I_0 e^{-\frac{t}{\tau}};\; \tau = \frac{L}{R}$$

Circuito L-C

F II

$$-L\frac{di}{dt}-\frac{q}{C}=0,\ \frac{d^2q}{dt^2}+\frac{1}{\mathrm{LC}}q=0$$

$$q=Q\cos(\omega t+\varphi);\ \omega=\sqrt{\frac{1}{LC}}$$

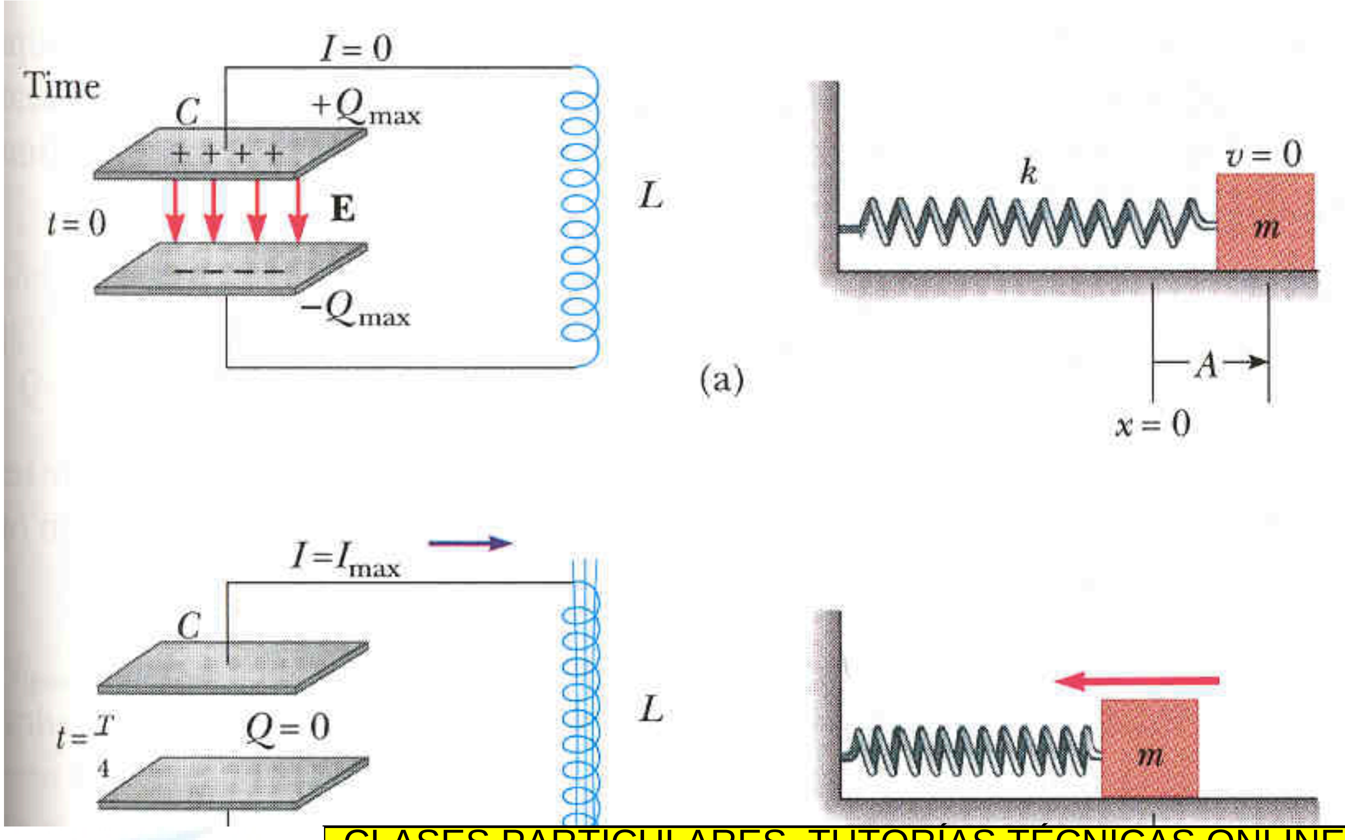
$$i=-\omega Q sen(\omega t+\varphi)$$

$$\frac{1}{2}Li^2+\frac{1}{2}\frac{q^2}{C}=\frac{1}{2}\frac{Q^2}{C}$$

$$i=\pm\sqrt{\frac{1}{LC}}\sqrt{Q^2-q^2}$$

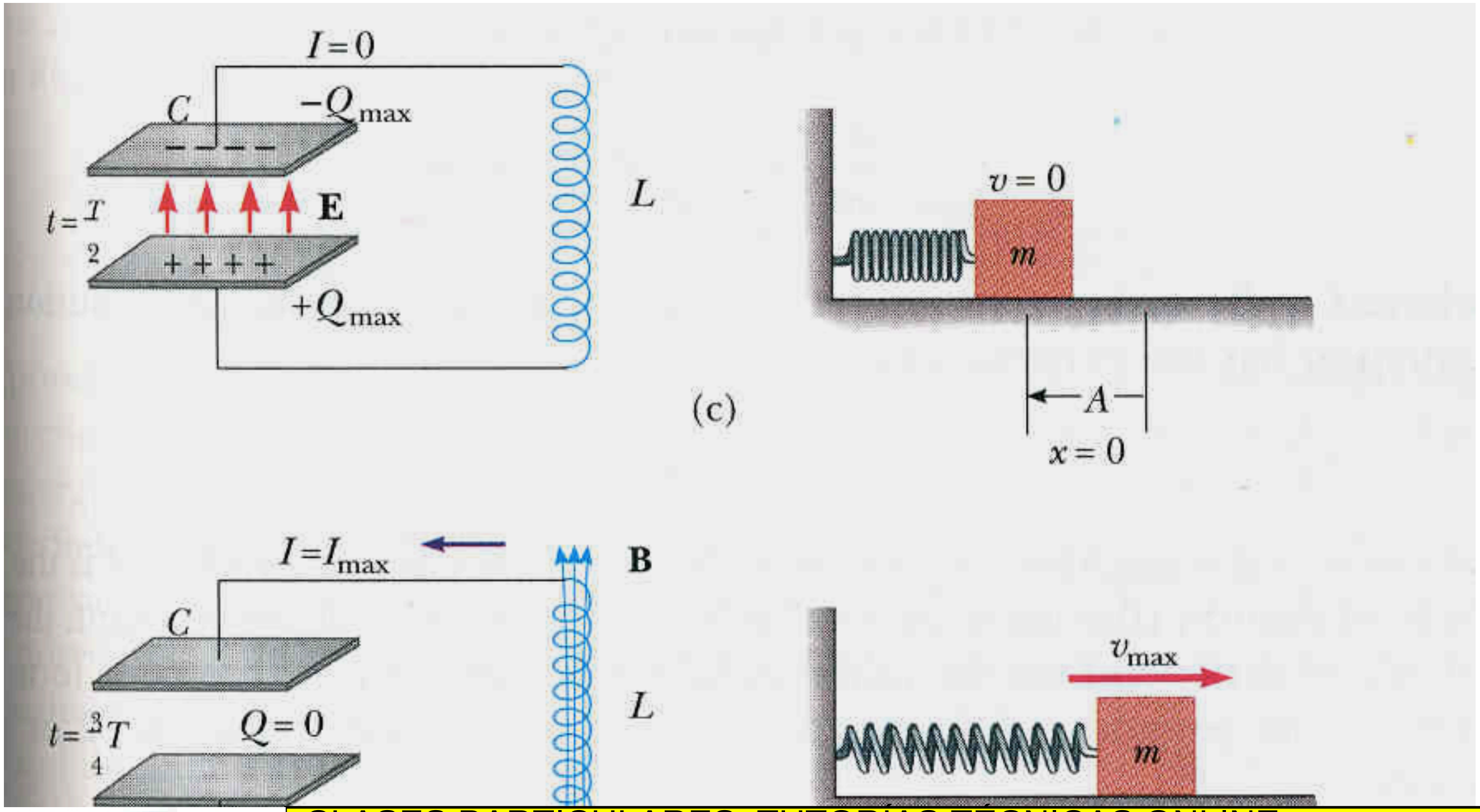
Circuito L-C

F II



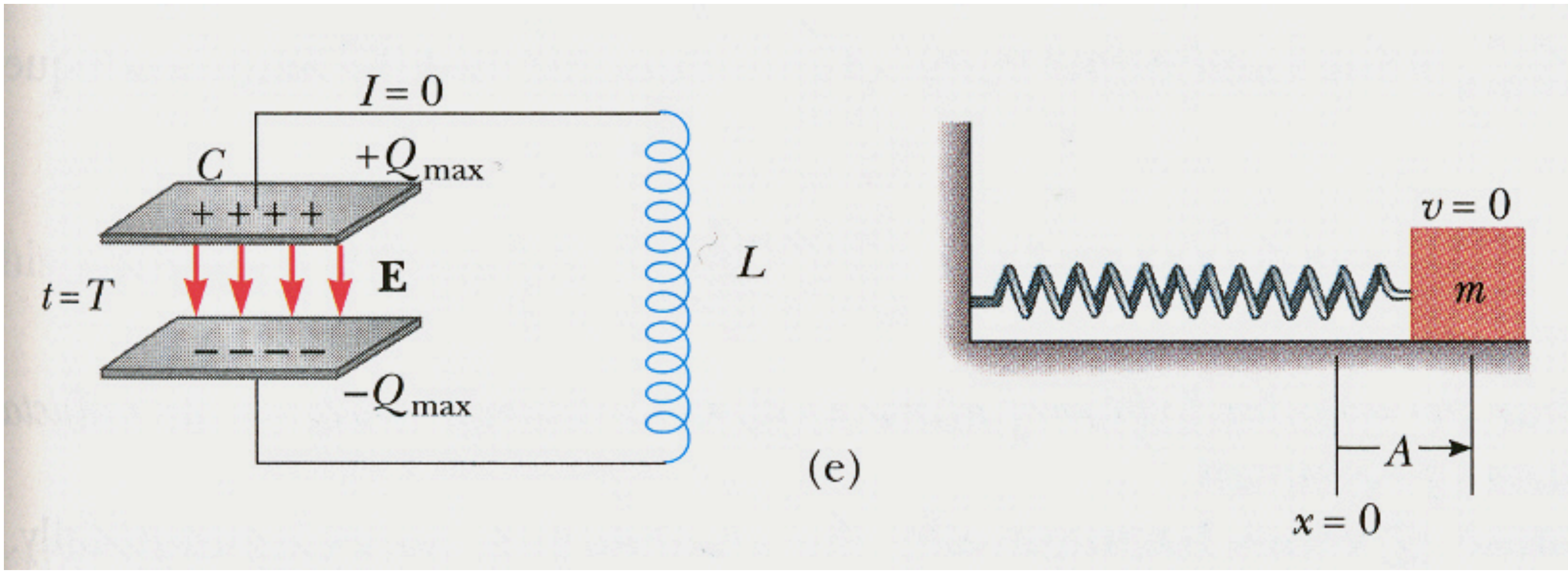
Circuito L-C

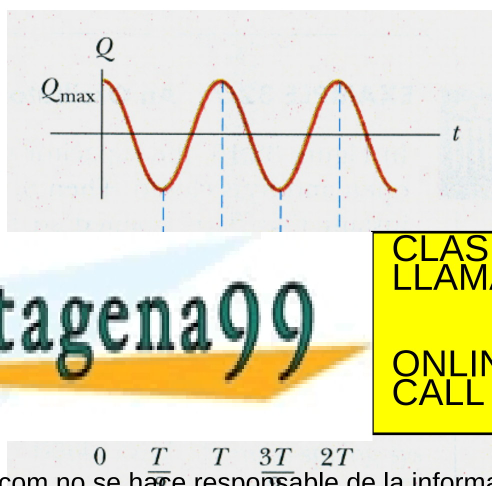
F II

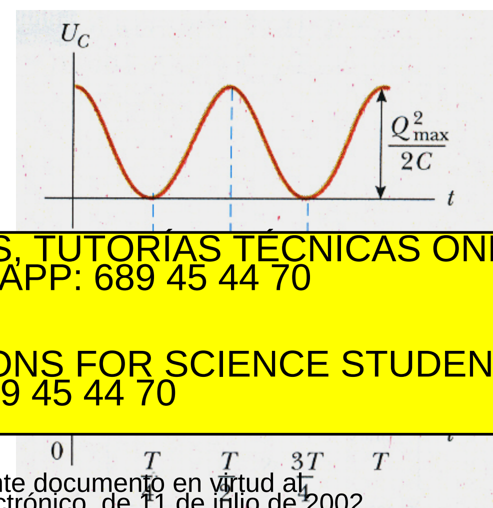


Circuito L-C

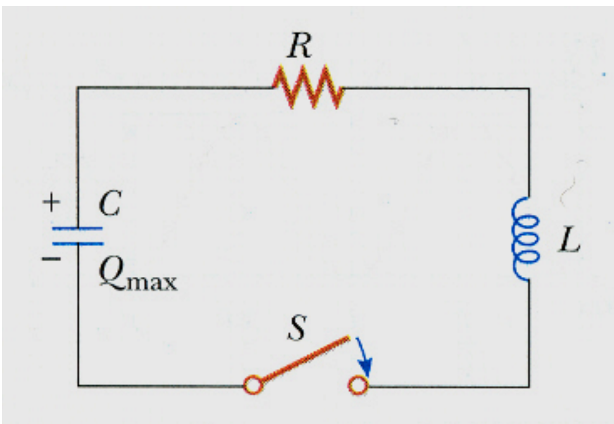
F II

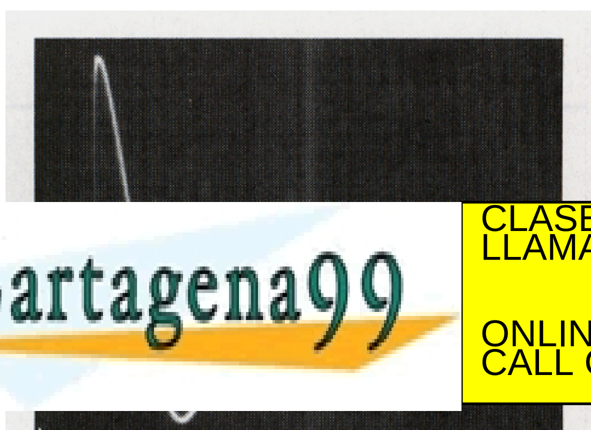






Circuito L-C-R





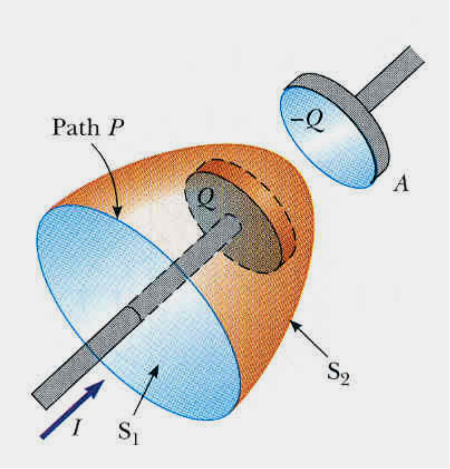
$$-iR - L\frac{di}{dt} - \frac{q}{C} = 0,\quad \frac{d^2q}{dt^2} + \frac{\mathrm{R}}{\mathrm{L}}\frac{dq}{dt} + \frac{1}{\mathrm{LC}}q = 0$$

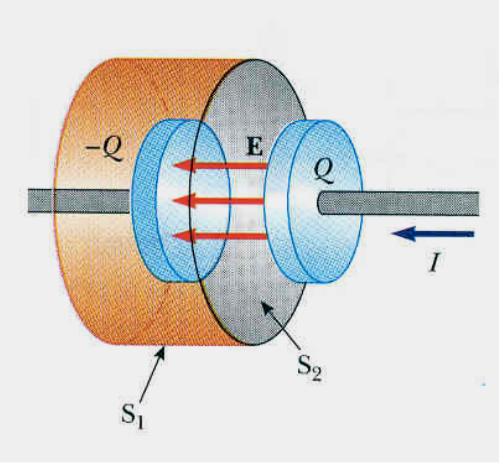
$$q = Ae^{-\left(\frac{R}{2L}\right)t}\cos(\omega' t + \varphi);\quad \omega' = \sqrt{\frac{1}{LC} - \frac{R^2}{4L^2}}$$

Corriente de desplazamiento

Carga condensador / ley Ampère

F II





Ecuaciones de Maxwell I

F II **En el vacío**

$$\oint_C \mathbf{E}\cdot d\mathbf{l} = -\frac{d}{dt}\int_A \mathbf{B}\cdot\mathbf{n}\,da \qquad \oint_S \mathbf{E}\cdot\mathbf{n}\,da = \frac{q}{\varepsilon_0}$$

$$\oint \mathbf{B}\cdot\mathbf{n}\,da = 0 \qquad \oint \mathbf{B}\cdot d\mathbf{l} = \mu_0\left(I + I_D\right) = \mu_0\int\left(\mathbf{j} + \varepsilon_0\frac{d\mathbf{E}}{dt}\right)\cdot\mathbf{n}\,da$$

Ecuaciones de Maxwell II

En medios materiales

F II

$$\oint_C \mathbf{E}\cdot d\mathbf{l} = -\frac{d}{dt}\oint_A \mathbf{B}\cdot \mathbf{n}da$$

$$\oint_S \mathbf{D}\cdot \mathbf{n}da = q$$

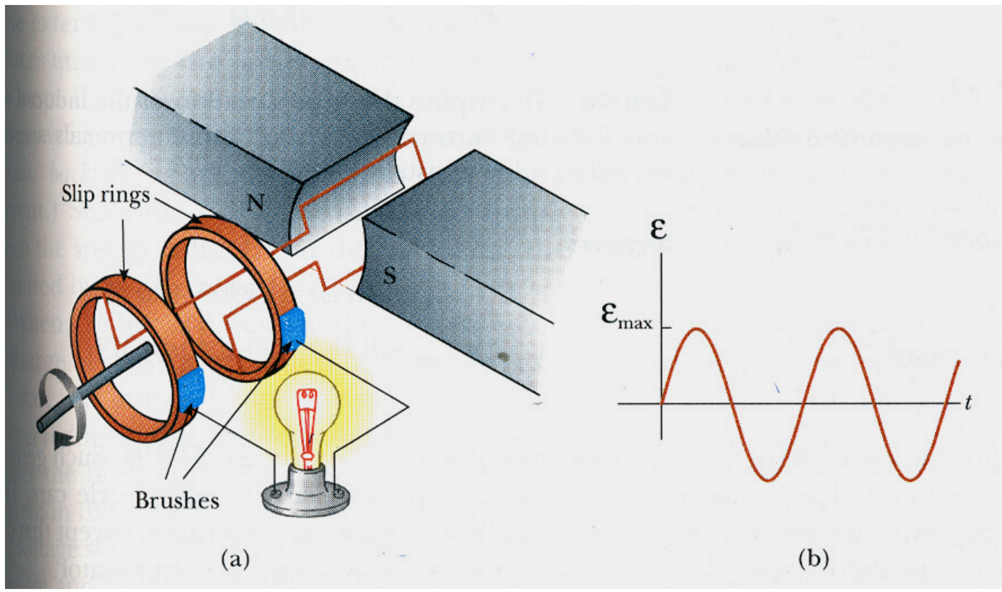
$$\oint_S \mathbf{B}\cdot \mathbf{n}\, da = 0$$

$$\oint_C \mathbf{H}\cdot d\mathbf{l} = \oint_C \left(\mathbf{j} + \frac{d\mathbf{D}}{dt}\right)\cdot \mathbf{n}da$$

Generación de corriente alterna

F II

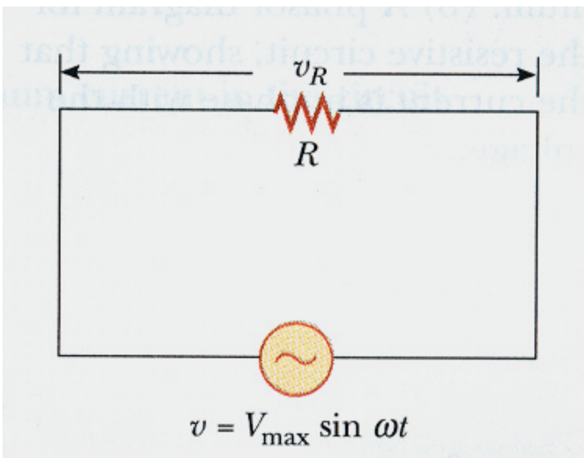
Campo uniforme+bobina giratoria

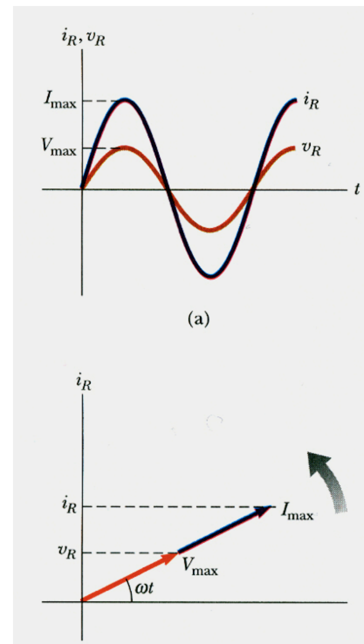


Corriente alterna I

F II

Resistencia pura R

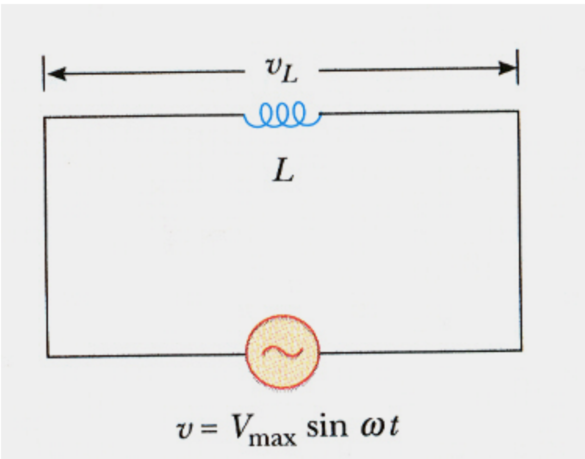


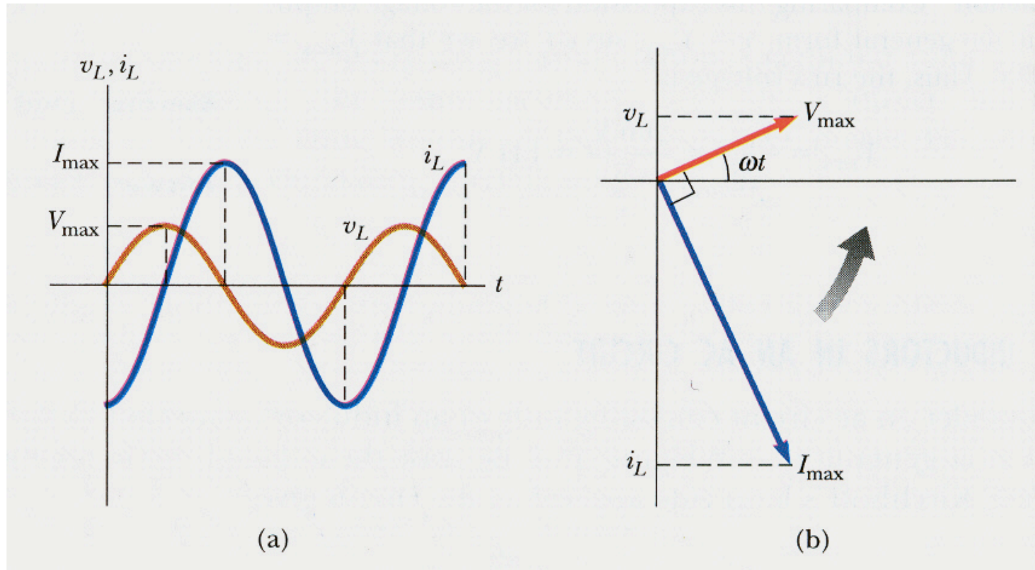


Corriente alterna II

Bobina ideal de autoinducción L

F II

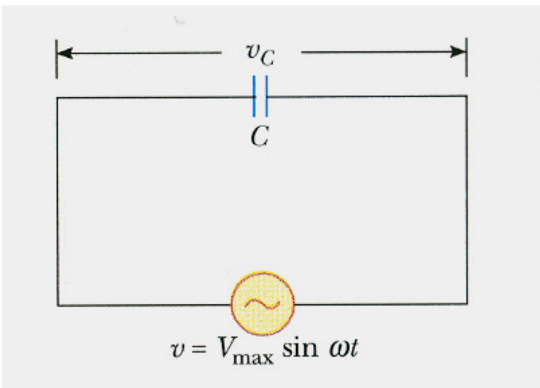


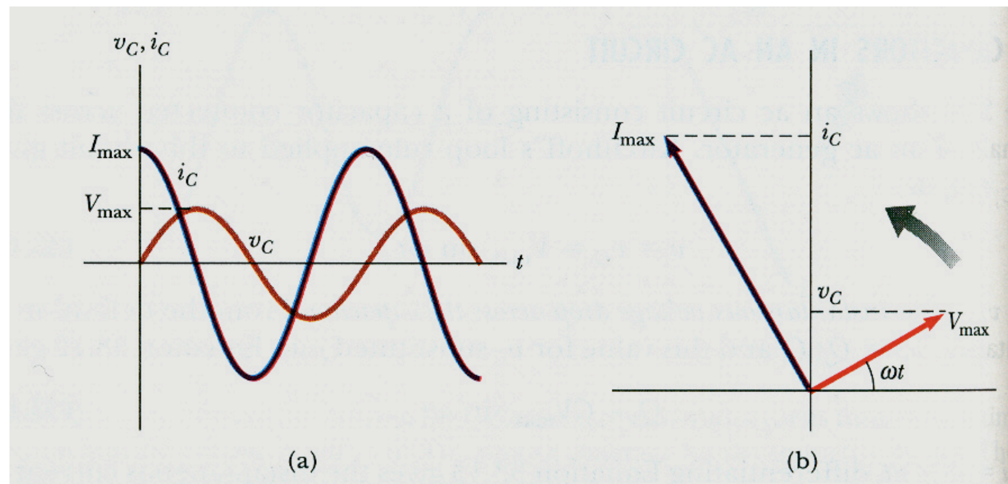


Corriente alterna III

F II

Condensador ideal de capacidad C

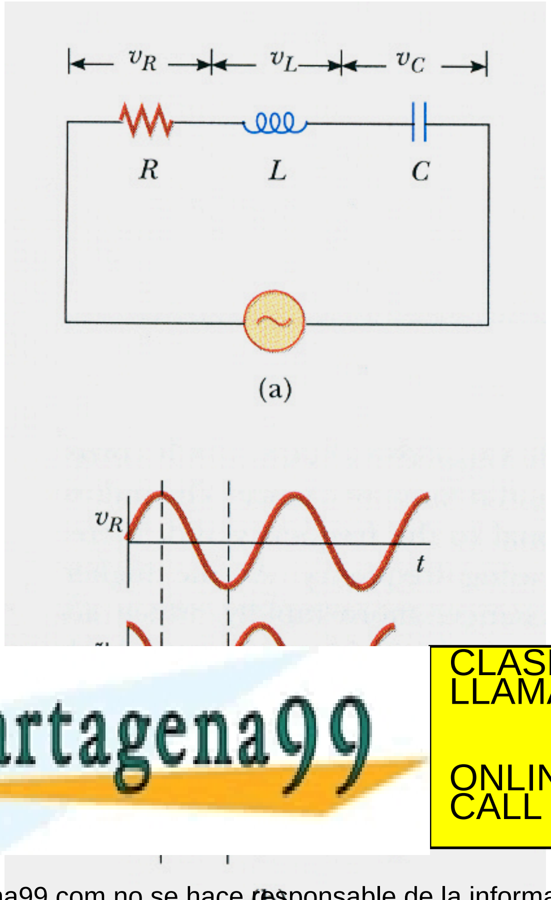




Corriente alterna IV

Circuito R-L-C

F II



$$v = V_0 sen\omega t;\ i = I_0 sen(\omega t - \phi)$$

$$v_R = I_0 R sen\omega t = V_R sen\omega t$$

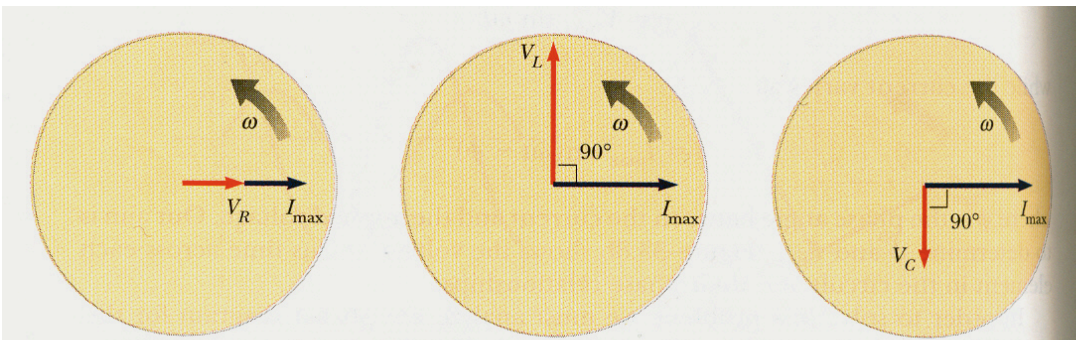
$$v_L = I_0 X_L sen\left(\omega t + \frac{\pi}{2}\right) = V_L \cos\omega t$$

$$v_C = I_0 X_C sen\left(\omega t - \frac{\pi}{2}\right) = -V_C \cos\omega t$$

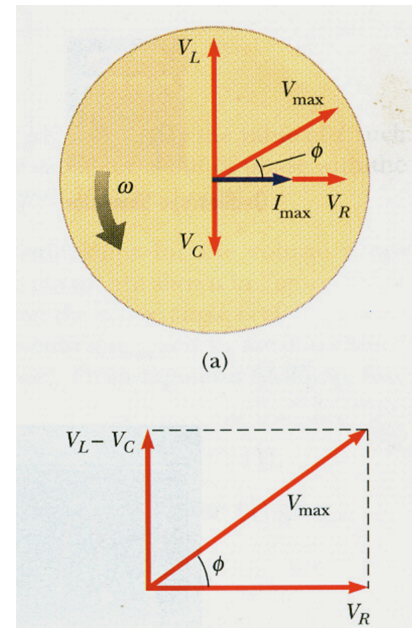
Corriente alterna V

Circuito R-L-C

F II



(a) (b) (c)



(a) (b)

$$v = v_R + v_L + v_C \; ; V_0 = \sqrt{V_R^{\,2} + (V_L - V_C)^2} = I_0 \sqrt{R^2 + (X_L - X_C)^2}$$

$$I_0 = \frac{V_0}{\quad} \; ; \; tg\phi = \frac{X_L - X_C}{\quad}$$

Corriente alterna VI

Circuito R-L-C

F II

$$v = V_0 sen\omega t;\ i = I_0 sen(\omega t - \phi)$$

$$v_R = I_0 R sen\omega t = V_R sen\omega t$$

$$v_L = I_0 X_L sen\left(\omega t + \frac{\pi}{2}\right) = V_L \cos\omega t$$

$$v_C = I_0 X_C sen\left(\omega t - \frac{\pi}{2}\right) = -V_C \cos\omega t$$

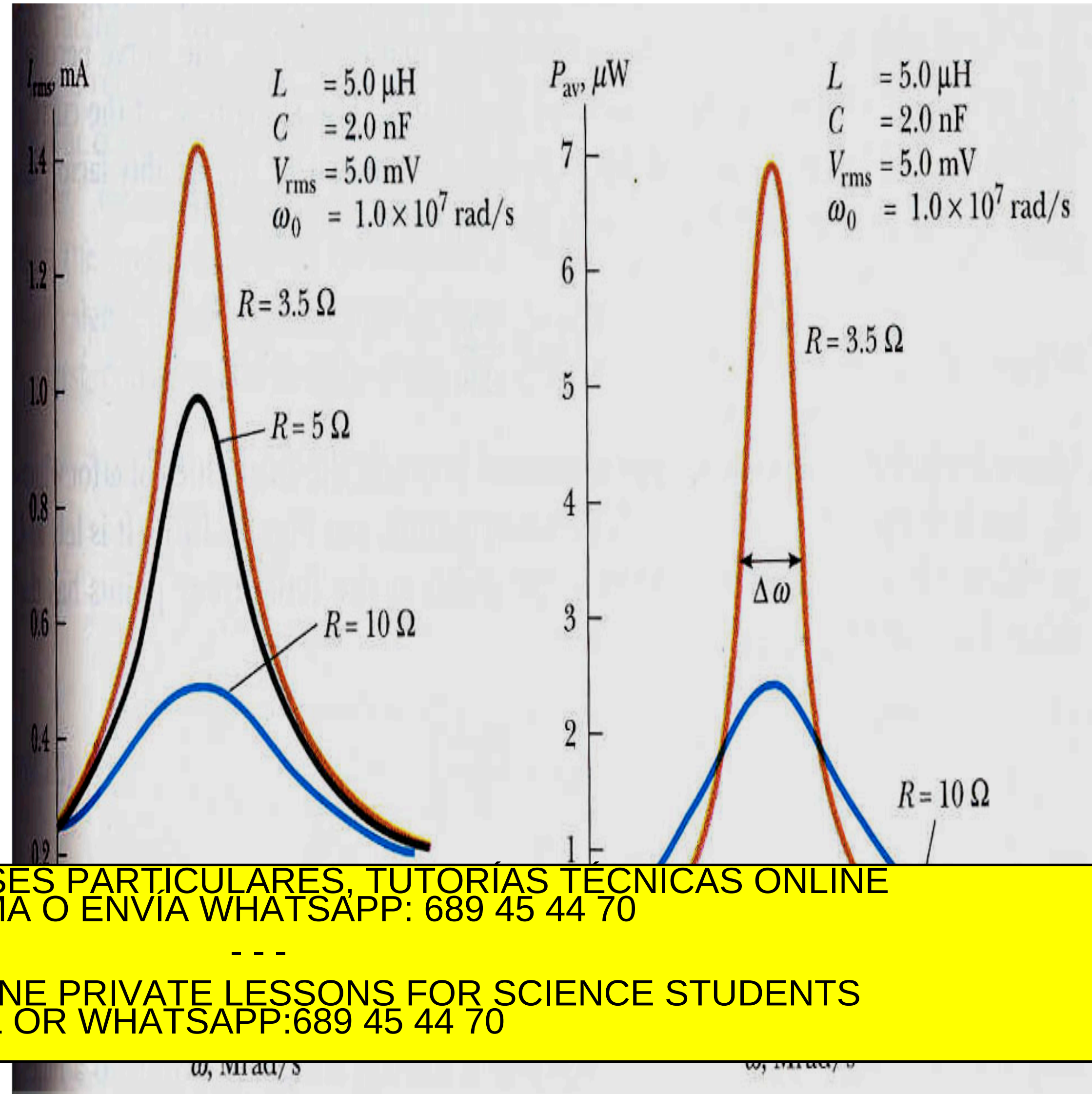
Circuit Elements	Impedance, Z	Phase angle, ϕ
R	R	0°
C	X_C	–90°
L	X_L	+90°
R, C	$\sqrt{R^2 + X_C^2}$	Negative, between –90° and 0°
R, L	$\sqrt{R^2 + X_L^2}$	Positive, between 0° and 90°
R, L, C	$\sqrt{R^2 + (X_L - X_C)^2}$	Negative if $X_C > X_L$ Positive if $X_C < X_L$

Resonancia

F II

$$\text{Si} \qquad \omega L = \frac{1}{\omega C}$$

$$\omega = \omega_r = \frac{1}{\sqrt{LC}}$$



Potencia circuito resistivo

F II

$$v = V_0\, sen\,\omega t;\; i = I_0\, sen\,\omega t$$

$$P_R(t) = V_0 I_0\, sen^2\,\omega t; \langle P_R \rangle = \frac{1}{T}\int_0^T P_R dt = \frac{V_0 I_0}{2}$$

$$V_{ef} = \frac{V_0}{\sqrt{2}} \text{ e } I_{ef} = \frac{I_0}{\sqrt{2}}$$

$\langle P_R \rangle$ ... $_{ef}$ ... R

Potencia circuito reactivo

F II

$$v = V_0 \, sen\,\omega t; \; i = I_0 \, sen\,(\omega t - \varphi)$$

$$P_R(t) = V_0 I_0 \, sen\,\omega t \; sen(\omega t - \varphi)$$

$$\langle P_R \rangle = \frac{1}{T}\int_0^T P_R dt = \frac{V_0 I_0}{2}\cos\varphi =$$

$$\frac{V_0}{\sqrt{2}}\frac{I_0}{\sqrt{2}}\cos\varphi = V_{ef}\, I_{ef}\cos\varphi$$

Transformadores

F II $$V_1 = -N_1 \frac{d\Phi}{dt;}; \; V_2 = -N_2 \frac{d\Phi}{dt;} \qquad \frac{V_1}{V_2} = \frac{N_1}{N_2}$$