ELECTROESTÁTICA $\vec{E}$

CAMPO CONSERVATIVO

$$\oint \vec{E} \cdot d\vec{r} = 0 \quad \text{(línea cerrada)}$$

LEY DE GAUSS

$$\oint \vec{E} \cdot d\vec{s} = \frac{\sum q_{int}}{\varepsilon_0}$$

(superficie cerrada)

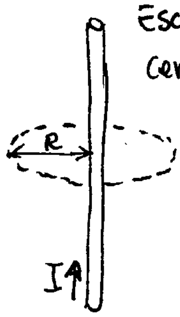
MAGNETOESTÁTICA $\vec{B}$

$$\oint \vec{B} \cdot d\vec{s} = 0 \quad \text{(sup cerrada)}$$

LEY DE AMPÈRE

$$\underbrace{\oint_{\Gamma}}_{\text{cerrada} \quad \text{línea}} \vec{B}\, d\vec{r} = \mu_0 \sum I_{int}$$

(línea cerrada)

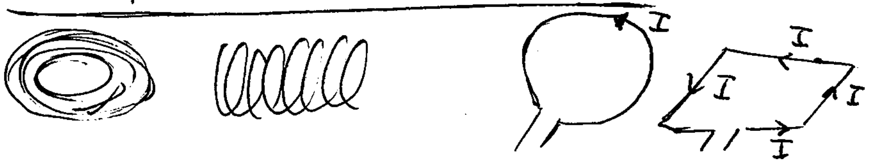


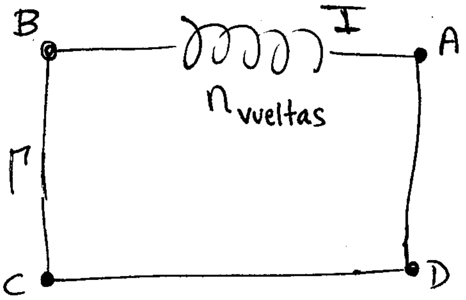
Escojo como línea (Γ) una circunferencia centrada en el hilo.

$$B \int_{\Gamma} dl = \mu_0 \cdot I \Rightarrow$$

$$\Rightarrow B\, 2\pi R = \mu_0 I \Rightarrow \boxed{B = \frac{\mu_0}{2\pi R} \cdot I}$$

BOBINA, SOLENOIDE, INDUCTANCIAS





$$\oint_{\Gamma} \vec{B} d\vec{r} = \int_A^B \vec{B} d\vec{r} + \int_B^C \cancel{\vec{B} \cdot d\vec{r}}^{\,0\ \perp} + \int_C^D \cancel{\vec{B} d\vec{r}}^{\,0\ \text{lejos}} + \int_D^A \cancel{\vec{B} \cdot d\vec{r}}^{\,0\ \perp}$$

$$\Rightarrow \oint_{\Gamma} \vec{B} d\vec{r} = \int_A^B \vec{B} d\vec{r} = \vec{B} \int_A^B d\vec{r} = B \cdot l$$

$$\Rightarrow \begin{cases} \oint \vec{B} \cdot d\vec{r} = \mu_0 \sum I_{int} \\ \oint \vec{B} \cdot d\vec{r} = B \cdot l \end{cases} \Rightarrow \mu_0 \sum I_{int} = B \cdot l \Rightarrow \boxed{B = \frac{\mu_0 N I}{l}}$$

$l = A - B$

$N = n_{vueltas} = n_{espiras}$

CAMPO CREADO POR UNA ESPIRA CIRCULAR EN SU CENTRO

$$\boxed{B = \frac{\mu_0 I}{2R}}$$

$R \rightarrow$ radio de la espira

TOROIDE

$$\boxed{B = \frac{\mu_0 N I}{2\pi R}}$$

FUERZA SOBRE UNA CARGA PUNTUAL QUE SE MUEVE EN UNA REGIÓN EN LA QUE $\exists \vec{B}$.

$$\boxed{\vec{F} = q\, \vec{v} \times \vec{B}}$$ LEY DE LORENTZ (fuerzas "Lorentzianas")

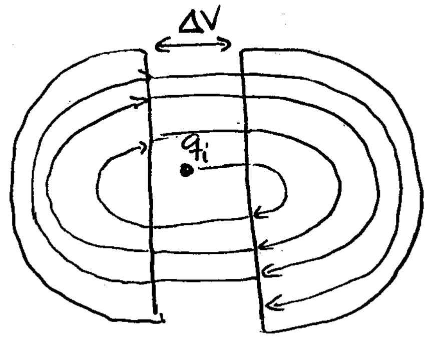
$|\vec{F}| = q v B \operatorname{sen}\theta_{vB}$; $\vec{F} \perp \vec{v}$ y $\vec{F} \perp \vec{B}$

Si $\vec{v} \perp \vec{B} \Rightarrow |\vec{F}| = qvB \cdot \overset{\operatorname{sen} 90}{\overset{\shortparallel}{1}} = qvB$

$$(*)\begin{cases} \text{Fuerzas centrípetas: } F = \dfrac{mv^2}{r} \\ \\ F_m = qvB \end{cases} \Rightarrow \boxed{qvB = \frac{mv^2}{R} \Rightarrow r = \frac{mv}{qB}}$$

$$\boxed{T = \frac{2\pi r}{v} = \frac{2\pi m}{qB}}$$

movimiento ciclotrón

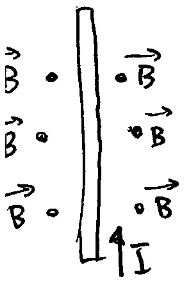


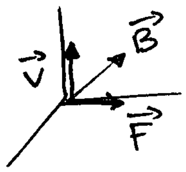
Fuerza magnética sobre corrientes eléctricas

$$\vec{F} = q\vec{v} \times \vec{B} \; ; \qquad \vec{v} = \frac{d\vec{l}}{dt} \Rightarrow \boxed{d\vec{F} = dq\,\frac{d\vec{l}}{dt} \times \vec{B} = I\, d\vec{l} \times \vec{B}}$$

$$\int dF = F_T = \int I\, d\vec{l} \times \vec{B} = I \int d\vec{l} \times \vec{B}$$

Fuerza magnética sobre un cable de longitud l con I bajo $\vec{B}_{uniforme}$



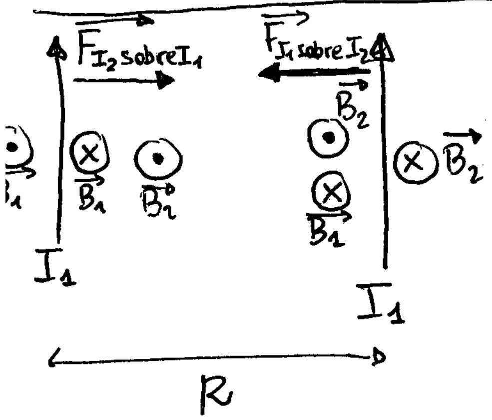


$$\vec{F} = I \int_\Gamma d\vec{l} \times \vec{B} = I \int_\Gamma (0, dl, 0) \times (0, 0, B) =$$

$$= I \int_\Gamma B\, dl\, \hat{\imath} = IB \int_\Gamma dl\, \hat{\imath} = IBL\,\hat{\imath}$$

FUERZA TOTAL: $F = IBL \Rightarrow \frac{F}{L} = IB$

FUERZAS ENTRE DOS CORRIENTES PARALELAS



I_1 crea B_1

I_2 "siente" B_2

I_2 crea B_2

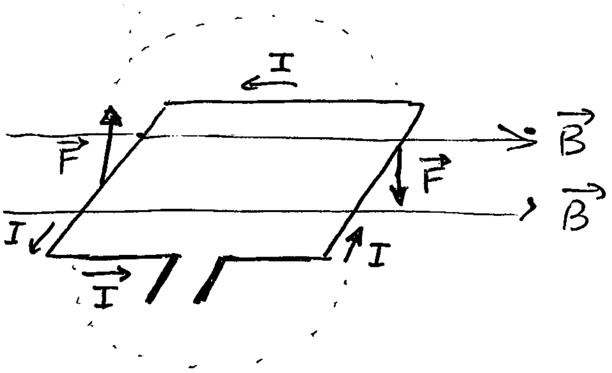
I_1 "siente" B_2

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

$$F_{1\to 2} = L B_1 I_2 = \frac{L \mu_0 I_1 I_2}{2\pi R}$$

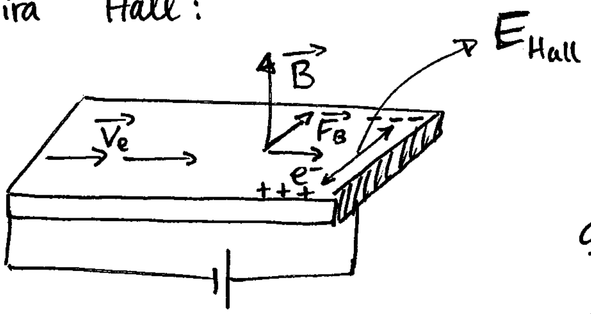
$$F_{2\to 1} = L B_2 I_1 = \frac{L \mu_0 I_1 I_2}{2\pi R}$$

Espira bajo un $\vec{B}$



Efecto Hall

Tira Hall:



$F_B = F_e$ cargas despl.

$$q\, v \times B = q\, E_{Hall}$$

$$\cancel{q} vB = \cancel{q} E_{Hall} \Rightarrow \boxed{E_{Hall} = vB}$$

$$\boxed{V_{Hall} = E \cdot d = vB \cdot d}$$

7. CAMPOS ELECTROMAGNÉTICOS

Un E variable en el tiempo $\longrightarrow$ crea B

Un B variable en el tiempo $\longrightarrow$ crea E

RECORDAR: Flujo

$$\phi_e = \int \vec{E} \cdot \hat{n}\, dA$$

$$\boxed{Wb = 1T \cdot m^2}$$

$$\phi_m = \int \vec{B} \cdot \hat{n}\, dA$$

LEY DE FARADAY

$$\boxed{fem = \mathcal{E} = \Delta V = \frac{-d\phi_m}{dt}}$$

OTRO RECUERDO

$$\phi_m = \int_S \vec{B} \cdot d\vec{s}$$

Ley de Faraday:

$$\mathcal{E} = f.e.m = \Delta V = -\frac{d\phi_m}{dt}$$

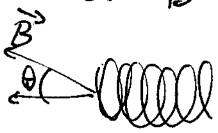
ojo con el signo, determina el sentido de la I_{in}

Ejemplo

Un B uniforme forma un $\theta = 30°$ con el eje de la bobina $N = 300$ y $R = 4c$

El B varía a razón de $85\ T/s$. Determinar la $\mathcal{E}$ inducida en la bobina.

$$\frac{dB}{dt}$$



N=300

$$\boxed{f.e.m = \mathcal{E} = \Delta V = -\frac{d\phi_m}{dt}}$$

$$\phi_m = \int_S \vec{B} \cdot d\vec{s} = \int B \cdot ds \cdot \cos\theta = B\cos\theta \int ds = B\cos\theta \cdot (\pi R^2) N$$

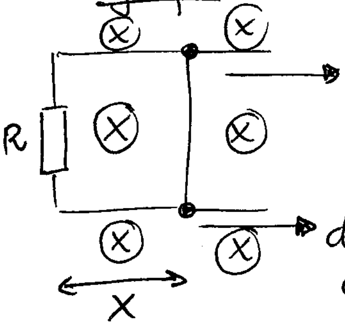
$$\mathcal{E} = -\frac{d\phi_m}{dt} = -\frac{d(B\cos\theta\, \pi R^2 N)}{dt} = -\pi R^2 N \cos\theta \cdot \frac{dB}{dt} =$$

solo varía el campo

$$= -\pi R^2 \cos\theta \cdot 85\ T/s = -\pi (0'04)^2 \cdot 300 \cdot \cos 30° \cdot 85 = \boxed{-111\ V}$$

Ejemplo

¿Cual es la $\mathcal{E}$ en mi circuito?



deslizamiento con V

$$\mathcal{E} = -\frac{d\Phi_m}{dt}$$

$$\Phi_m = \int_S \vec{B}\cdot d\vec{s} = \int B\, ds \cos\theta = B \underbrace{\cos\theta}_{1} \int ds = B.\,\text{área} = B.\ell.\overset{\text{varía}}{x}$$

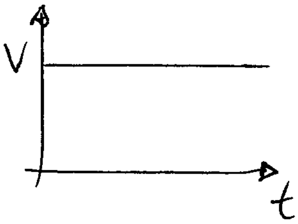
$$\boxed{x = x_0 + V.t}$$

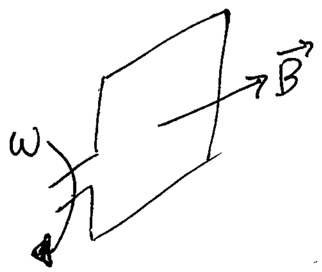
$$\mathcal{E} = -\frac{d\Phi_m}{dt} = -\frac{d(B.\ell.x)}{dt} = -B.\ell.\frac{dx}{dt} = \boxed{-B.\ell.V}$$

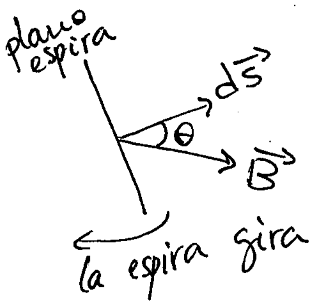
$$I = \frac{\mathcal{E}}{R} = \frac{B.\ell.V}{R} \quad \text{sentido antihorario}$$

APLICACIÓN DE LA LEY DE FARADAY

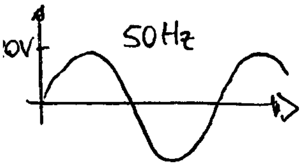
- Generador de corriente alterna







$$\theta = \overset{\text{velocidad angular}}{\omega} t + \underset{\text{ángulo inicial}}{\theta_0}$$



t

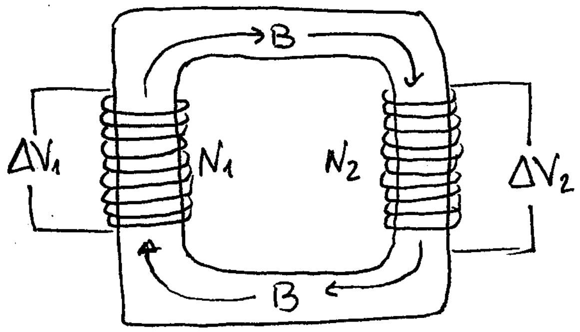
$$\Phi_m = \int \vec{B}\cdot d\vec{s} = BS\cos\theta = BS\cos(\omega t + \theta_0)$$

$$\mathcal{E} = -\frac{d\Phi_m}{dt} = -\frac{d}{dt}\left(BS\cos(\omega t+\theta_0)\right) = -B.S.\frac{d}{dt}\left(\cos(\omega t+\theta_0)\right) \Rightarrow$$

$$\Rightarrow \boxed{\mathcal{E} = B.S.\,\omega\,\text{sen}(\omega.t + \theta_0)}$$

▸ Transformador

in $\longrightarrow \Delta V_1$ (transform.) $\Delta V_2 \longrightarrow$ out



El material magnético nos asegura que:

flujo por espira 1 $\rightarrow \phi_{e_1} = \phi_{e_2} \leftarrow$ flujo por espira 2

flujo bobina 1 $\rightarrow \phi_{b_1} = N_1 \cdot \phi_e$

$$\phi_{b_2} = N_2 \cdot \phi_e$$

$$\Delta V_1 = -\frac{d\phi_{b1}}{dt} = -N_1 \cdot \frac{d\phi_e}{dt} \quad (1)$$

$$\Delta V_2 = \frac{-d\phi_{b2}}{dt} = -N_2 \cdot \frac{d\phi_e}{dt} \quad (2)$$

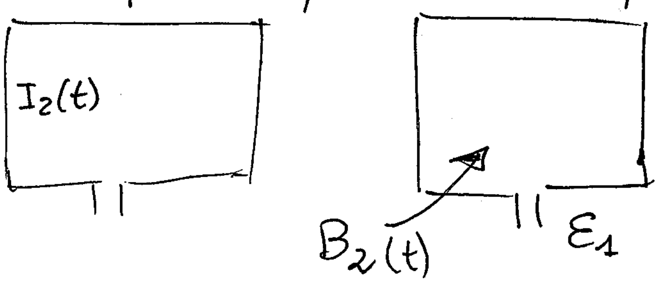
$$(1) \rightarrow \frac{-d\phi_e}{dt} = \frac{\Delta V_1}{N_1}$$

$$(2) \rightarrow \frac{-d\phi_e}{dt} = \frac{\Delta V_2}{N_2}$$

$$\Rightarrow \frac{\Delta V_1}{N_1} = \frac{\Delta V_2}{N_2} \Rightarrow \boxed{\Delta V_2 = \Delta V_1 \cdot \frac{N_2}{N_1}}$$

INDUCCIÓN MUTUA

Sean dos circuitos C_1 y C_2 y por uno circula una corriente que depende del tiempo.



COEFICIENTE DE INDUCCIÓN DE 2 SOBRE 1

$$\boxed{\mathcal{E}_1 = -M_{12}\frac{dI_2}{dt}}$$

$$\boxed{\phi_{12} = M_{12} I_2}$$

$$\mathcal{E}_1 = -M_{12}\frac{dI_2}{dt} = \frac{-d\phi_{12}}{dt}$$ ~ flujo de 2 produce sobre 1.

$$S.I\,[M_{12}] = \frac{T.m^2}{A} = H \text{ (henrio)}$$

HUTOINDUCCIÓN

COEFICIENTE DE AUTOINDUCCIÓN

Analogamente $\Phi_{12} = M_{12} I_2$

$\Phi = L I$

$$\boxed{L = \frac{\Phi}{I}}$$

COEFICIENTE DE AUTOINDUCCIÓN
|||
INDUCTANCIA

Coeficiente de autoinducción de una bobina

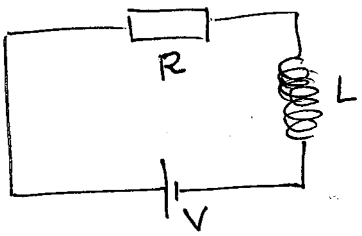
$$L = \frac{\phi}{I} = \mu_0 n N \pi r^2 = \mu_0 \frac{N^2}{\ell} \pi r^2$$

SÓLO DEPENDE DE LA GEOMETRÍA

El $B_{int} = \mu_0 n I$

El, $\Phi_{int} = \mu_0 n I \cdot \text{Área} = \mu_0 n I \cdot N \pi r^2$

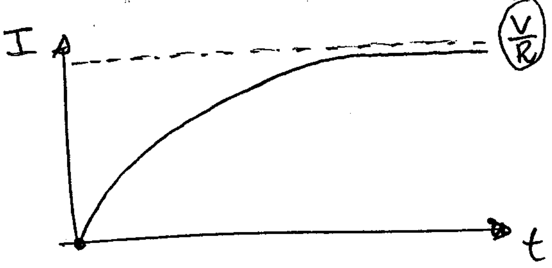
BOBINAS EN CIRCUITOS
||
INDUCTANCIAS



$$V = IR + \Delta V_L$$

$$V = IR + L \cdot \frac{dI}{dt}$$

$$I(t) = \frac{V}{R}\left(1 - e^{-\frac{R}{L} \cdot t}\right) = \frac{V}{R}\left(1 - e^{-t/\tau}\right)$$

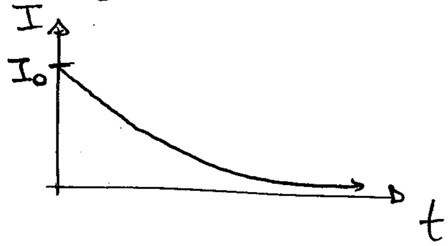


τ (tiempo característico) =

$$= \frac{L}{R} \Rightarrow \boxed{\tau = \frac{L}{R}}$$

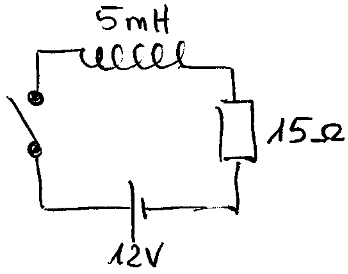
Si imponemos $I_0 \rightarrow I(0) = I_0$

$$\Rightarrow I = I_0 \cdot e^{-\frac{R}{L}t}$$



Energía almacenada en una bobina: $\boxed{U_m = \frac{1}{2} \cdot L \cdot I^2}$

Ejemplo:



en $t=0$ cerramos el interruptor

a) I para $t \rightarrow \infty$

b) τ del circuito

c) ¿Cuanto tiempo (medido en τs) hasta que la I alcanza el 99% de su valor final?

d) ¿Energía almacenada en la bobina?

a) $I_F = \frac{V}{R} = \frac{12}{15} = \boxed{0'8 \text{ A}}$

b) $\tau = \frac{L}{R} = \frac{5 \cdot 10^{-3}}{15} = \boxed{3'33 \cdot 10^{-4} \text{ s}}$

c) ¿$\frac{t}{\tau}$? para $\frac{I}{I_F} = 0'99 \rightarrow I = I_F\left(1 - e^{-t/\tau}\right) \rightarrow e^{-t/\tau} = 1 - \frac{I}{I_F} \Rightarrow$

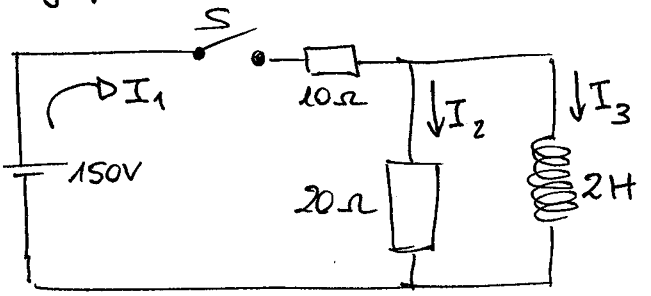
ln

$\Rightarrow \frac{-t}{\tau} = \ln\left(1 - \frac{I}{I_F}\right) \Rightarrow \frac{t}{\tau} = -\ln\left(1 - \frac{I}{I_F}\right) \Rightarrow$

$\Rightarrow \frac{t}{\tau} = -\ln(1 - 0'99) = 4'61 \Rightarrow \boxed{t = 4'61\ \tau}$

d) $U_m = \frac{1}{2} \cdot L \cdot I^2 = 1'6 \cdot 10^{-3}$ J

Ejemplo: En $t=0$ cerramos S, determinar I.



a) Justo después de cerrar S

b) Un tiempo largo después de cerrar S.

Pasado ese tiempo abrimos S.

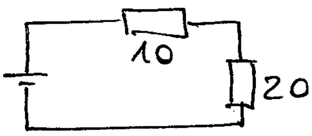
c) I justo después de abrirlo.

d) ~~Un t largo de~~ I un t largo después de abrir

$$\boxed{I_1 = I_2 + I_3}$$

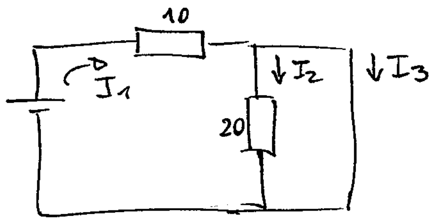
a) $I_3 = 0$

$I_1 = I_2$



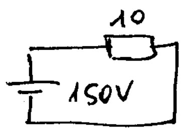
$150 = I_1(10+20) \Rightarrow I_1 = 5A$

b)



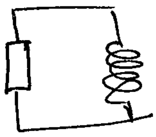
$I_2 = 0$

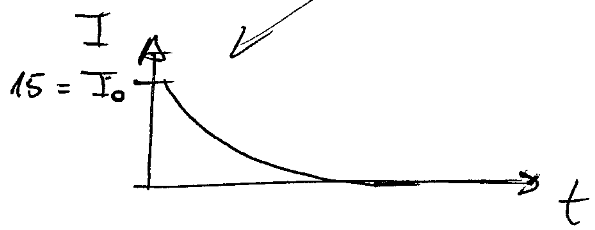
$I_1 = I_3$



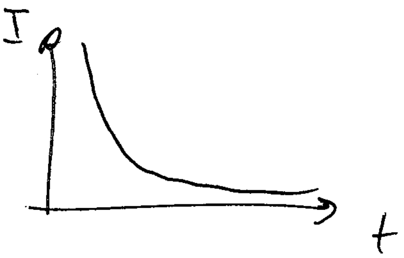
$I = 15A$

c) $I = 15A$



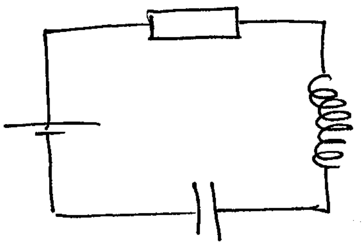


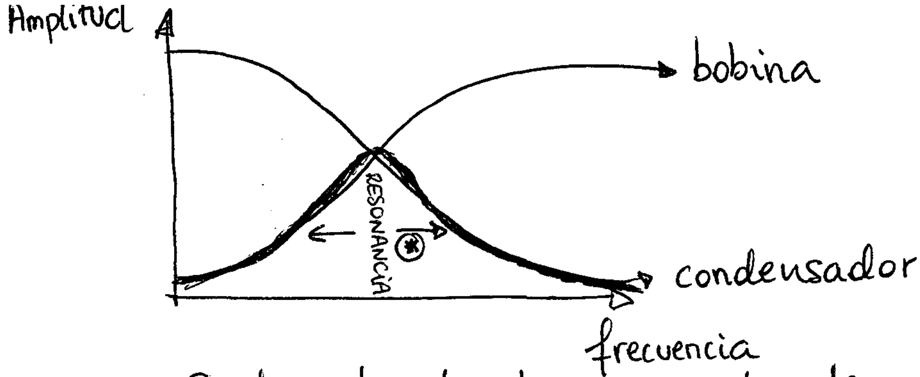
d)



$I_1 = I_2 = I_3 = 0$

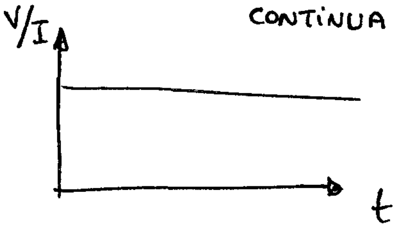
después de un tiempo largo la intensidad tiende a cero.

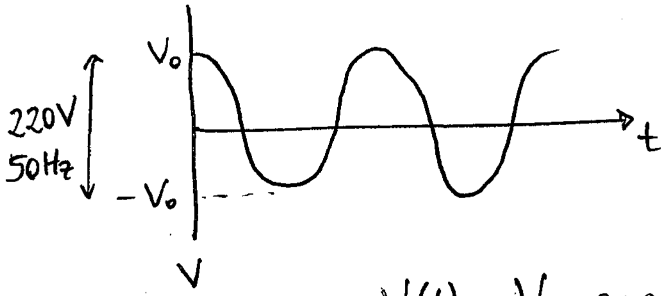




⊛ el ancho de la curva depende de la resistencia

TEMA 8: CIRCUITOS DE CORRIENTE ALTERNA



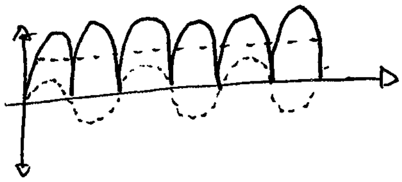


$$V(t) = V_0 \cdot \text{sen}(\omega t)$$

$$V(t) = V_0 \cdot \cos\left(\omega t + \frac{\pi}{2}\right)$$

$$V_0 \simeq V_{max} = \frac{V_{pp}}{2}$$

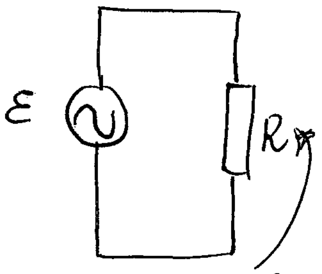
Valores eficaces



$$V_{eff} = \sqrt{\langle V^2 \rangle}$$

definición general

$$V_{eff} = \frac{V_0}{\sqrt{2}} \quad ; \quad I_{eff} = \frac{I_0}{\sqrt{2}}$$



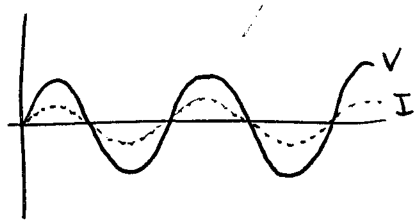
RESISTENCIA

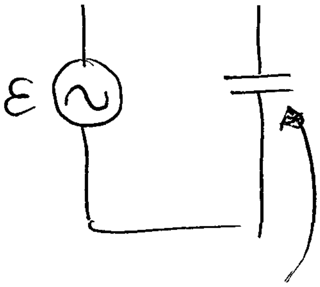
(~) fuente de V en alterna

$$\mathcal{E} = \mathcal{E}_{max}\,\text{sen}(\omega t + \varphi)$$

$$V_R = I \cdot R \rightarrow I = \frac{V}{R} = \frac{\mathcal{E}}{R} = \frac{\mathcal{E}_{max}\,\text{sen}(\omega t + \varphi)}{R}$$

$$\begin{cases} \mathcal{E} = \mathcal{E}_{max} \cdot \text{sen}(\omega t + \varphi) \\ I = \dfrac{\mathcal{E}_{max} \cdot \text{sen}(\omega t + \varphi)}{R} \end{cases}$$





CONDENSADOR

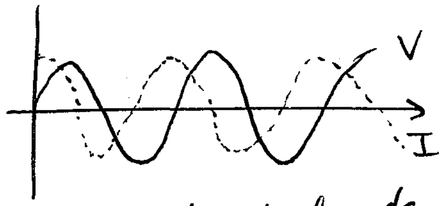
~ fuente de V

$$\mathcal{E} = \mathcal{E}_{max} \cdot \operatorname{sen}(\omega t + \varphi)$$

$$Q = C \cdot V_c = C \cdot \mathcal{E} = C \cdot \mathcal{E}_{max} \cdot \operatorname{sen}(\omega t + \varphi)$$

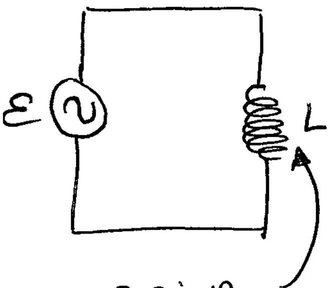
$$I = \frac{dQ}{dt} = C \cdot \mathcal{E}_{max} \cdot \omega \cdot \cos(\omega t + \varphi) \equiv C \cdot \mathcal{E}_{max} \cdot \omega \cdot \operatorname{sen}\left(\omega t + \varphi + \frac{\pi}{2}\right)$$

$$\begin{cases} \mathcal{E} = \mathcal{E}_{max} \cdot \operatorname{sen}(\omega t + \varphi) \\ I = C \cdot \mathcal{E}_{max} \cdot \omega \cdot \operatorname{sen}\left(\omega t + \varphi + \frac{\pi}{2}\right) \end{cases}$$



corriente desfasada

$$\boxed{\chi_c = \frac{1}{C \cdot \omega} \quad \text{reactancia capacitiva o capacitancia}}$$



BOBINA

~ fuente de V

$$\mathcal{E} = \mathcal{E}_{max} \cdot \operatorname{sen}(\omega t + \varphi)$$

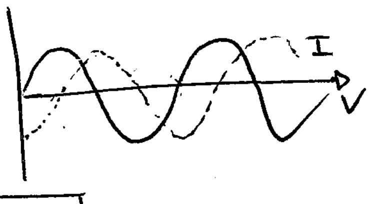
$$V_L = V_{\mathcal{E}} = L \cdot \frac{dI}{dt}$$

$$\frac{dI}{dt} = \frac{\mathcal{E}}{L} \Rightarrow I = \int \frac{\mathcal{E}}{L} dt = \int \frac{\mathcal{E}_{max}}{L} \cdot \operatorname{sen}(\omega t + \varphi)\, dt =$$

$$= \frac{-\mathcal{E}_{max}}{\omega \cdot L} \cos(\omega t + \varphi)$$

$$I = \frac{\mathcal{E}_{max}}{\omega \cdot L} \cdot \operatorname{sen}\left(\omega t + \varphi - \frac{\pi}{2}\right)$$

$$\begin{cases} \mathcal{E} = \mathcal{E}_{max} \cdot \operatorname{sen}(\omega t + \varphi) \\ I = \frac{\mathcal{E}_{max}}{\omega L} \cdot \operatorname{sen}\left(\omega t + \varphi - \frac{\pi}{2}\right) \end{cases}$$

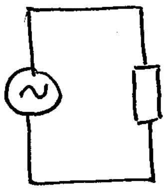


$$\boxed{\chi_L = \omega \cdot L \quad \text{reactancia inductiva o inductancia}}$$

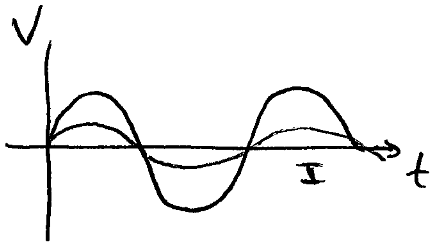
$\boxed{\varepsilon = \varepsilon_{max} \cdot sen(\omega t + \varphi)}$

RECUERDO

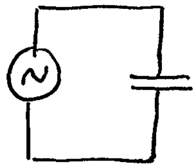
R



$$I = \frac{\varepsilon_{max}}{R} \cdot sen(\omega t + \varphi)$$

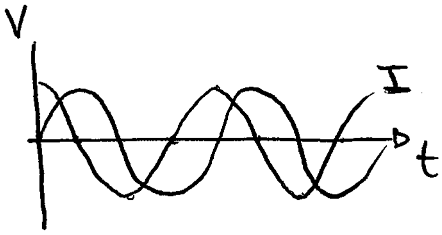


C

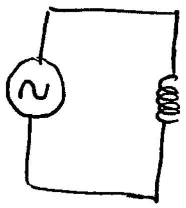


$$I = \frac{\varepsilon_{max}}{1/\omega . C} \cdot sen(\omega t + \varphi + \pi/2)$$

$1/\omega . C$ ⟶ X_c reactancia capacitiva

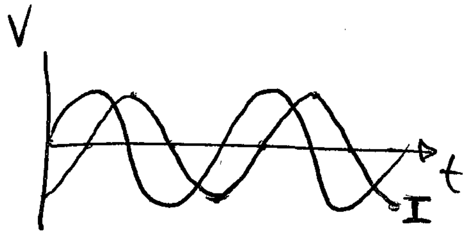


L



$$I = \frac{\varepsilon_{max}}{\omega . L} \cdot sen\left(\omega t + \varphi - \frac{\pi}{2}\right)$$

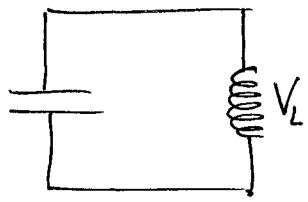
$\omega . L$ ⟶ X_L reactancia inductiva



CIRCUITO LC SIN GENERADOR

Condensador inicialmente cargado Q_0

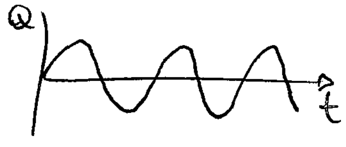
C



$$V_L + V_C = 0 \Rightarrow L . \frac{dI}{dt} + \frac{Q}{C} = 0 \Rightarrow \qquad I = \frac{dQ}{dt}$$

$$\Rightarrow \boxed{L \frac{d^2Q}{dt} + \frac{Q}{C} = 0}$$

$$Q = Q_0 . \cos\left(\frac{1}{\sqrt{LC}} \cdot t\right)$$



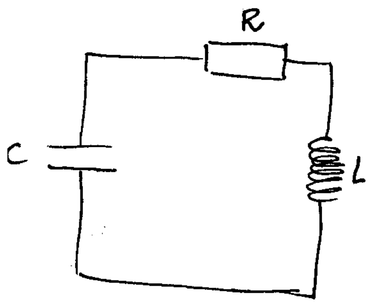
$\omega = \frac{1}{\sqrt{LC}}$ frecuencia natural del circuito

$$\boxed{I = I_0 . sen\left(\frac{1}{\sqrt{LC}} \cdot t\right) \ ; \quad \omega = \frac{1}{\sqrt{LC}}}$$

Corriente oscilante en el tiempo con una frecuencia de $\omega = \frac{1}{\sqrt{LC}}$

* Esto sería en un mundo ideal, en el que los cables, condensar y bobina NO tenga resistencia.

Circuito RLC sin generador

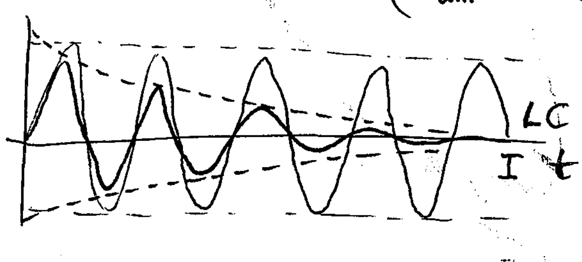


$$V_R + V_L + V_C = 0 \Rightarrow$$

$$\Rightarrow I \cdot R + L \cdot \frac{dI}{dt} + \frac{Q}{C} = 0 \Rightarrow$$

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

$$Q(t) = Q_0 \cdot e^{-\gamma t} \cdot \operatorname{sen}(\omega_{am} \cdot t + \varphi_0)$$



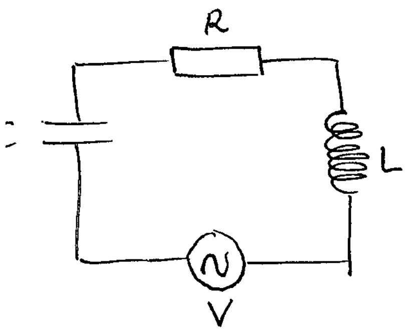
$$\longrightarrow \gamma = \frac{R}{2L}$$

$$\longrightarrow \boxed{\omega_{am}^2 = \omega_0^2 - \gamma^2 \approx \omega_0^2}$$

γ^2 muy peque

$$\omega_0 = \frac{1}{\sqrt{LC}}$$

Circuito RLC con generador



$$V = V_{max} \cdot \cos(\omega t)$$

$$V_B + V_C + V_L + V_R = 0$$

$$I = I_{max} \cdot \cos(\omega t - \varphi)$$

donde $\varphi = \dfrac{X_L - X_C}{R}$

$$I_{max} = \frac{V_{max}}{\sqrt{R^2 + (X_L - X_C)^2}} \rightarrow Z = \sqrt{R^2 + (X_L - X_C)^2}$$

impedancia total del circuito

¿cuándo circula más corriente? (ω en que I_{max})

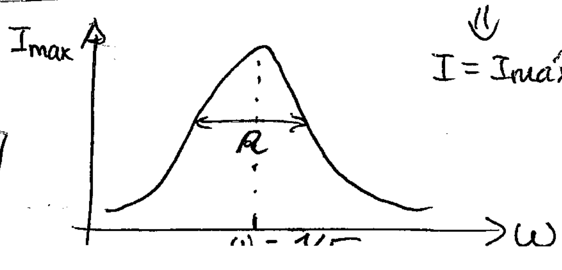
I será máx cuando Z es mínimo $\Rightarrow$ Z es mínimo cuando $(X_L - X_C)^2 =$

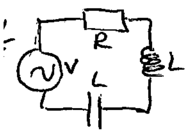
$$\Rightarrow X_L - X_C = 0 \Rightarrow \omega L - \frac{1}{\omega C} = 0 \Rightarrow \boxed{\omega = \frac{1}{\sqrt{LC}} = \omega_0}$$

frecuencia de resonancia

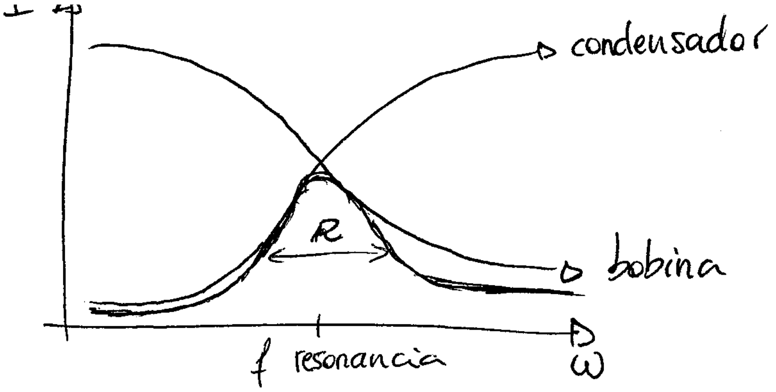
$\Downarrow$

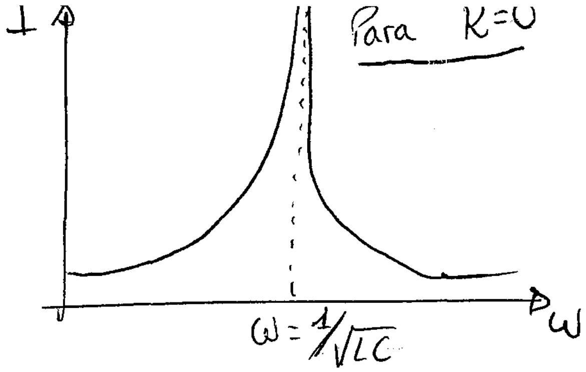
$I = I_{máx}$





$$I = \frac{\mathcal{E}_{max}}{\sqrt{R^2 + (X_L - X_C)^2}} \cdot \operatorname{Sen}(\omega t - \varphi)$$

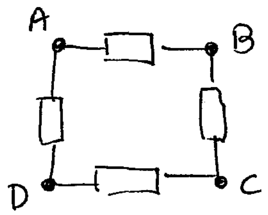




Potencia disipada en RLC?

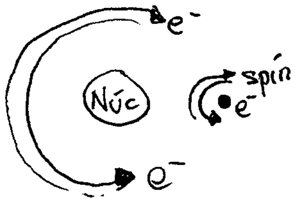
$$P_{disipada\_media} = I_{eff}^2 \cdot R$$

Observación



$$V_{eff_{AC}} = \sqrt{V_{eff_{AB}}^2 + V_{eff_{BC}}^2}$$

PROPIEDADES MAGNÉTICAS DE LA MATERIA



$\varepsilon \begin{cases} \text{dieléctricos/aislantes} \\ \text{conductores} \end{cases}$ $\vec{E}$

$\varepsilon \rightarrow$ permeabilidad eléctrica

$\mu \begin{cases} \text{paramagnéticos} & \chi_m > 0 & \text{pequeña } \mu > 1 \\ \text{ferromagnéticos} & \chi_m >>> 0 & \mu >>> 1 \\ \text{diamagnéticos} & \chi_m < 0 & \mu < 1 \end{cases}$

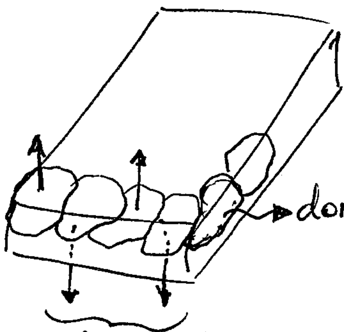
$\mu \rightarrow$ permeabilidad magnética del medio

$$\boxed{\vec{B}_T = \vec{B}_{ext} \underbrace{(1 + \chi_m)}_{\mu}}$$

$\chi_m \rightarrow$ susceptibilidad magn.

$\mu \rightarrow$ permeabilidad magn. del medio

MATERIAL FERROMAGNÉTICO



$\rightarrow$ dominios magnéticos

los podemos orientar en dos direcciones dependiendo de la orientación del campo magnético que le aplicamos.