JEE MAIN

ALTERNATING CURRENT

FORMULAE

Now that's how you REVISE

-Mohit Goenka, IIT Kharagpur

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ALTERNATING CURRENT

1. Average and RMS current
2. R, L, C taken individually in circuit (Phase relation)
3. LR Circuit across AC source
4. RC Circuit across AC source
5. LC Circuit across AC Source
6. RLC Series
7. Power in AC Circuit and Power factor
8. Resonant Frequency in RLC Series
9. Current variation with frequency, Bandwidth, Quality factor
10. RLC in Parallel
11. Transformer

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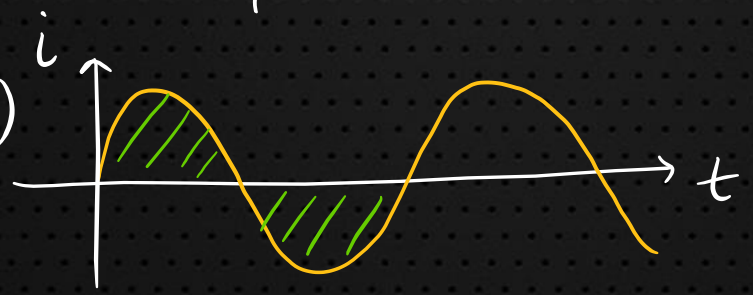
1. I_{av} AND I_{rms}

$$I_{av} = \frac{\int_{t_1}^{t_2} i(t)\,dt}{t_2 - t_1}$$

$$I_{rms} = \sqrt{\frac{\int_{t_1}^{t_2} i^2(t)\,dt}{t_2 - t_1}}$$

NOTE: $\int i\,dt$ is area under i v/s t curve

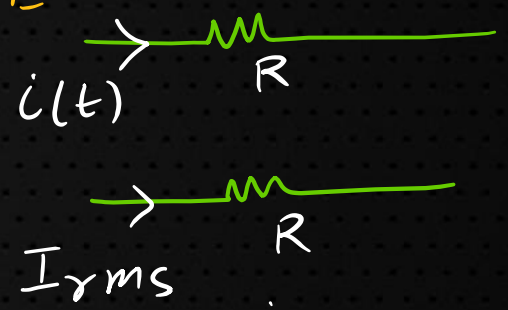
(i)



for $i = i_0 \sin\omega t$

$i_{av} = 0$

NOTE:



In same time, same heat is dissipated

Ex: If $i = i_0 \sin\omega t$

$i_{rms} = i_0/\sqrt{2}$

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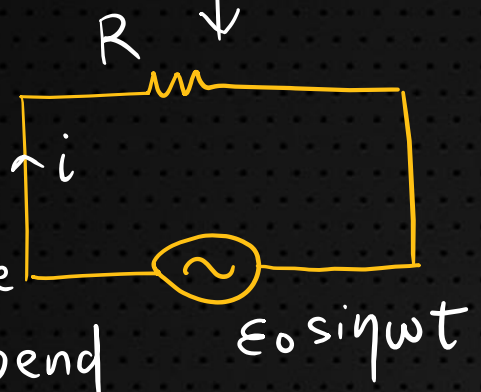
2. PHASE RELATION BETWEEN $\mathcal{E}$ AND i (R, L, C TAKEN INDIVIDUALLY)

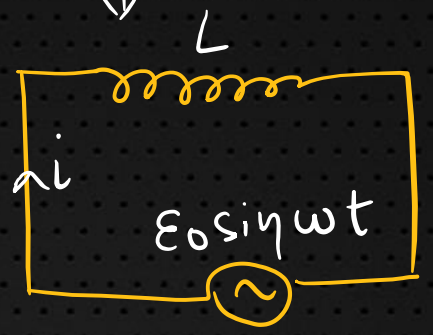
$i = i_0 \sin \omega t$

(a) $i_0 = \mathcal{E}_0 / R$

(b) i and $\mathcal{E}$ in phase

(c) R doesn't depend on ω





$i = i_0 \sin\left(\omega t - \frac{\pi}{2}\right)$

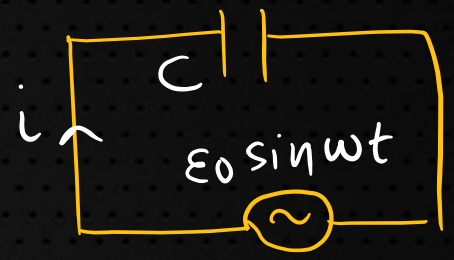
(a) $i_0 = \frac{\mathcal{E}_0}{X_L}$, $X_L = \omega L$

↳ Inductive Reactance

(b) i lags by $\pi/2$

(c) At $\omega \to 0$, $X_L \to 0$

$\omega \to \infty$, $X_L \to \infty$



$i = i_0 \sin\left(\omega t + \frac{\pi}{2}\right)$

(a) $i_0 = \mathcal{E}_0 / X_C$

$X_C = 1/\omega C$

↓ CAPACITIVE REACTANCE

(b) i leads by $\pi/2$

(c) At $\omega \to 0$, $X_C \to \infty$

$\omega \to \infty$, $X_C \to 0$

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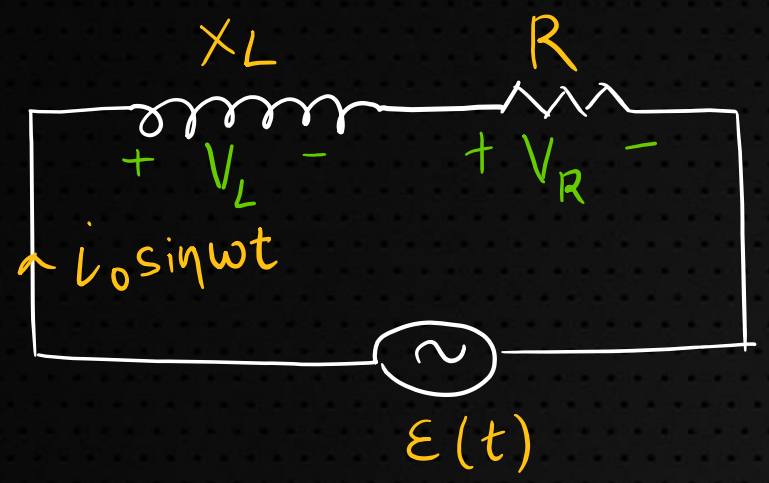
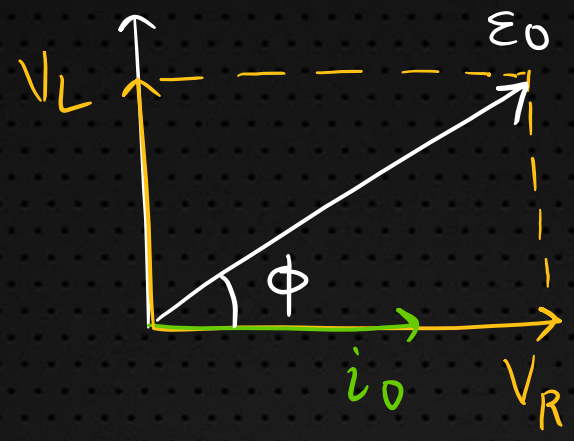
3. LR CIRCUIT (PHASOR Dig.)





$$\mathcal{E}_0 = \sqrt{V_L^2 + V_R^2}$$

$$\Rightarrow i_0 Z = \sqrt{(i_0 X_L)^2 + (i_0 R)^2}$$

$$Z = \sqrt{X_L^2 + R^2} \rightarrow \text{Impedance}$$

$$\tan\phi = \frac{V_L}{V_R} = \frac{X_L}{R}$$

(a) $Z = \sqrt{X_L^2 + R^2}$

(b) $\tan\phi = X_L / R$

(c) $\mathcal{E}$ leads i by ϕ

$\therefore \mathcal{E} = \mathcal{E}_0 \sin(\omega t + \phi)$

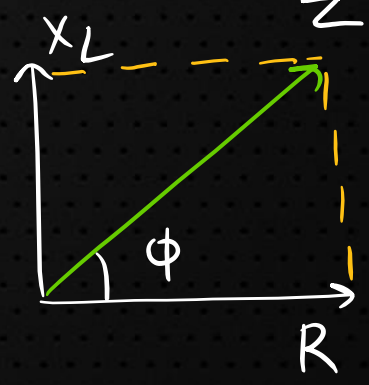
$\hookrightarrow \mathcal{E}_0 = i_0 Z$

(d) $v_L = V_L \sin(\omega t + \pi/2)$

$\hookrightarrow V_L = i_0 X_L$

NOTE:

$Z = \sqrt{R^2 + X_L^2}$



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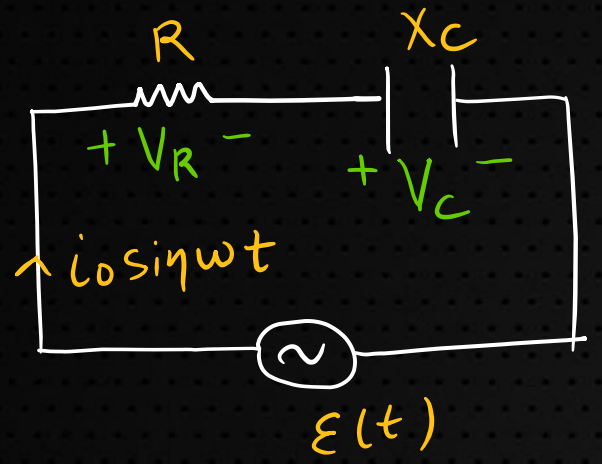
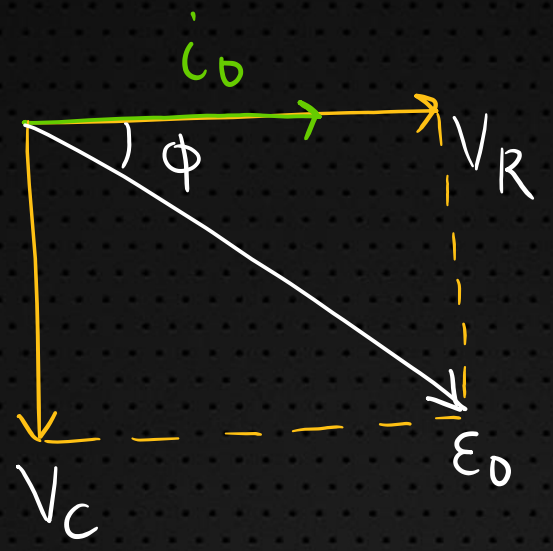
4. RC CIRCUIT





$$\mathcal{E}_0 = \sqrt{V_R^2 + V_C^2}$$

$$i_0 Z = \sqrt{(i_0 R)^2 + (i_0 X_C)^2}$$

$$\Rightarrow Z = \sqrt{R^2 + X_C^2}$$

$\hookrightarrow$ Impedance

$$\tan\phi = \frac{V_C}{V_R} = \frac{X_C}{R}$$

(a) $Z = \sqrt{X_C^2 + R^2}$, $X_C = \frac{1}{\omega C}$

(b) $\tan\phi = X_C / R$

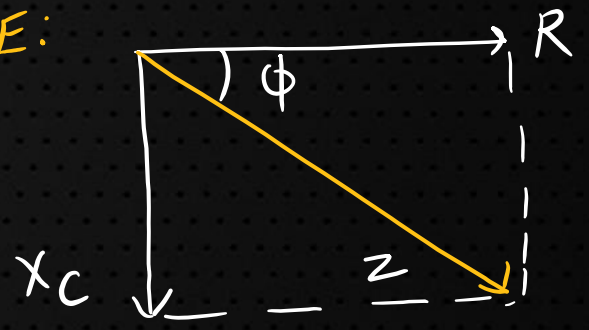
(c) $\mathcal{E}$ lags i by ϕ

$\therefore \mathcal{E} = \mathcal{E}_0 \sin(\omega t - \phi)$

$\hookrightarrow \mathcal{E}_0 = i_0 Z$

(d) $v_C = V_C \sin(\omega t - \frac{\pi}{2})$

NOTE:



$$Z = \sqrt{R^2 + X_C^2}$$

$$\tan\phi = X_C / R$$

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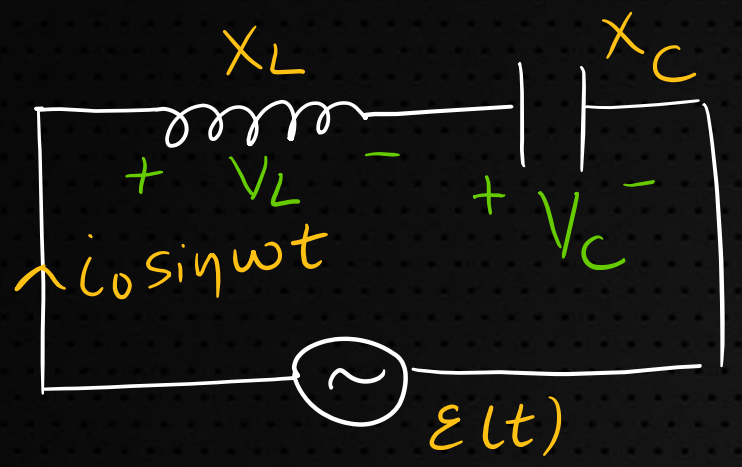
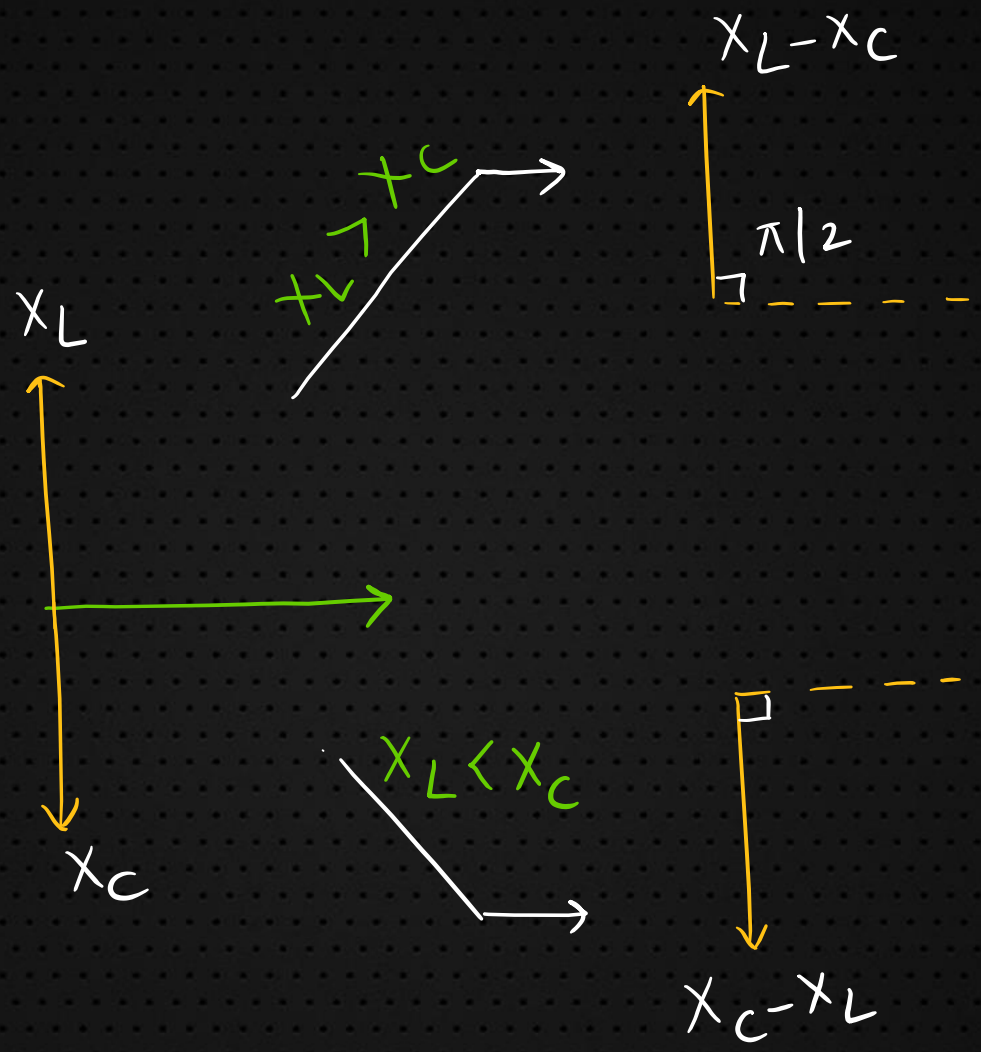
5. LC CIRCUIT





(a) $Z = X_L - X_C$

(b) $\mathcal{E}$ leads i by $\pi/2$

(c) $\mathcal{E} = \mathcal{E}_0 \sin\left(\omega t + \frac{\pi}{2}\right)$

$\hookrightarrow i_0 Z$

(a) $Z = X_C - X_L$

(b) $\mathcal{E}$ lags i by $\pi/2$

(c) $\mathcal{E} = \mathcal{E}_0 \sin\left(\omega t - \frac{\pi}{2}\right)$

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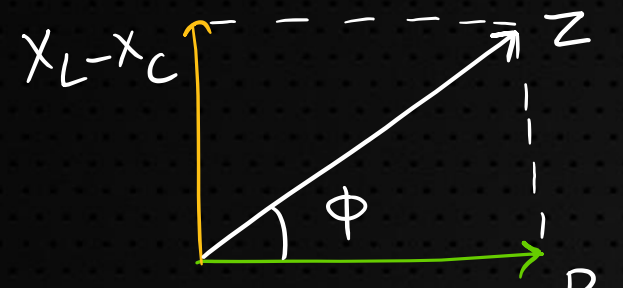
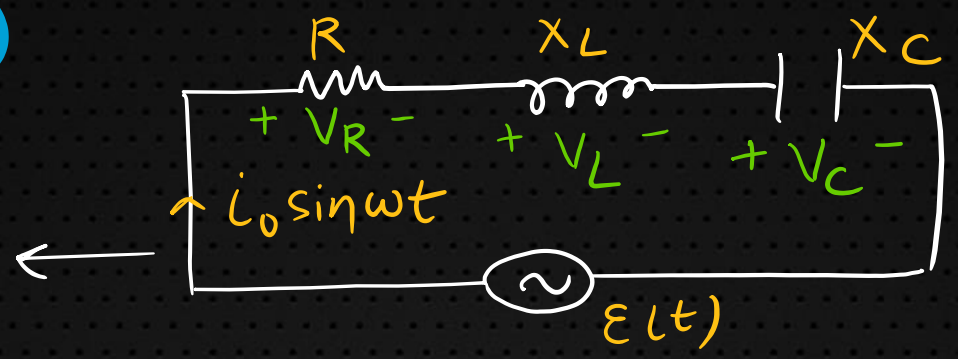
6. RLC (SERIES)



$$Z = \sqrt{R^2 + (X_L - X_C)^2}$$

$$\tan\phi = \frac{X_L - X_C}{R}$$



(a) If $X_L > X_C$ (Inductive) $\Rightarrow$ $\mathcal{E}$ leads by ϕ

$\mathcal{E} = \mathcal{E}_0 \sin(\omega t + \phi)$

$\hookrightarrow i_0 Z$

If $X_C > X_L$ (capacitive) $\Rightarrow$ $\mathcal{E}$ Lags by ϕ

$\hookrightarrow \mathcal{E} = \mathcal{E}_0 \sin(\omega t - \phi)$

(b) $v_L = V_L \sin(\omega t + \pi/2)$

$\hookrightarrow V_L = i_0 X_L$

$v_C = V_C \sin(\omega t - \pi/2)$

$\hookrightarrow V_C = i_0 X_C$

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7. POWER IN AC CIRCUIT

$$P_{av} = \mathcal{E}_{rms}\, i_{rms} \cos\phi$$

NOTE: In questions If nothing mentioned, take given supply voltage as $\mathcal{E}_{rms}$.

Power factor, $\cos\phi = R/Z$

- → only C, $\cos\phi = 0 \Rightarrow P_{av} = 0$
- → only L, $\cos\phi = 0, \Rightarrow P_{av} = 0$
- → only R, $\cos\phi = 1, \Rightarrow P_{av}$ is Max
- → RL, $\cos\phi = \dfrac{R}{\sqrt{X_L^2 + R^2}}$
- → RC, $\cos\phi = \dfrac{R}{\sqrt{X_C^2 + R^2}}$
- → RLC, $\cos\phi = \dfrac{R}{\sqrt{R^2 + (X_L - X_C)^2}}$

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8. RESONANT FREQUENCY (SERIES RLC)

↳ That value of ω for which impedance is purely resistive. $(Z = R)$

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

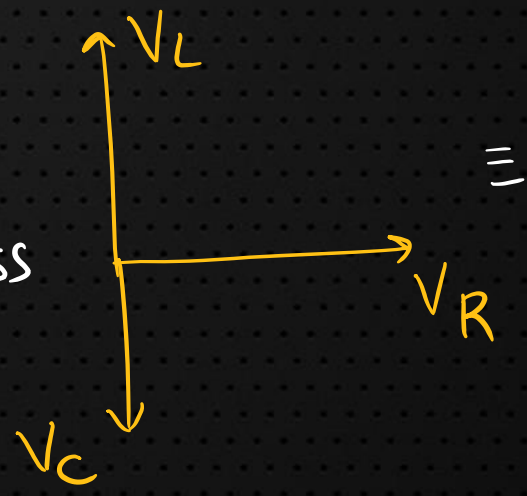
$\therefore$ for $\omega L = \frac{1}{\omega C}$, $Z = R$ $\Rightarrow$ $\omega_R = \frac{1}{\sqrt{LC}}$

(b) At resonance, $P_{av} = i_{rms}^2 R = \frac{\varepsilon_{rms}^2}{R}$ $(\cos\phi = 1)$

(c) $\because X_L = X_C$

$\Rightarrow V_L = V_C$

$\therefore$ All supply is across Resistor.



$\equiv$ $\longrightarrow V_R$

$\therefore \varepsilon_0 = V_R$

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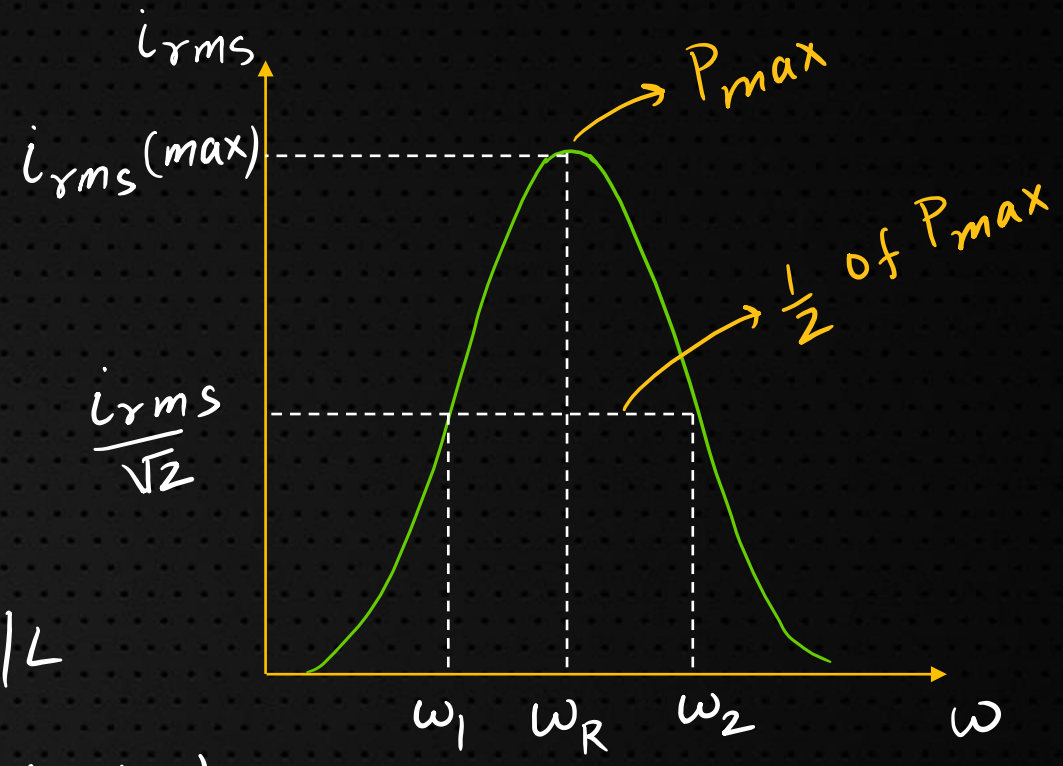
9. CURRENT VARIATION WITH ω (SERIES RLC)

$$i_{rms} = \frac{\mathcal{E}_{rms}}{\sqrt{R^2 + \left(\omega L - \frac{1}{\omega C}\right)^2}}$$



(a) For ω_1 and ω_2
P_{av} is $\frac{1}{2}$ of P_{max}.

(b) BANDWIDTH
$$\Delta\omega = \omega_2 - \omega_1 = R/L$$

(c) QUALITY FACTOR (Q factor)
$$Q = \frac{\omega_R}{\Delta\omega} = \frac{1}{\sqrt{LC}} \times \frac{L}{R} = \frac{1}{R}\sqrt{\frac{L}{C}}$$

(d) If $\omega < \omega_R \Rightarrow X_C > X_L$ (i leads)

(e) $\omega > \omega_R \Rightarrow X_L > X_C$ (i lags)

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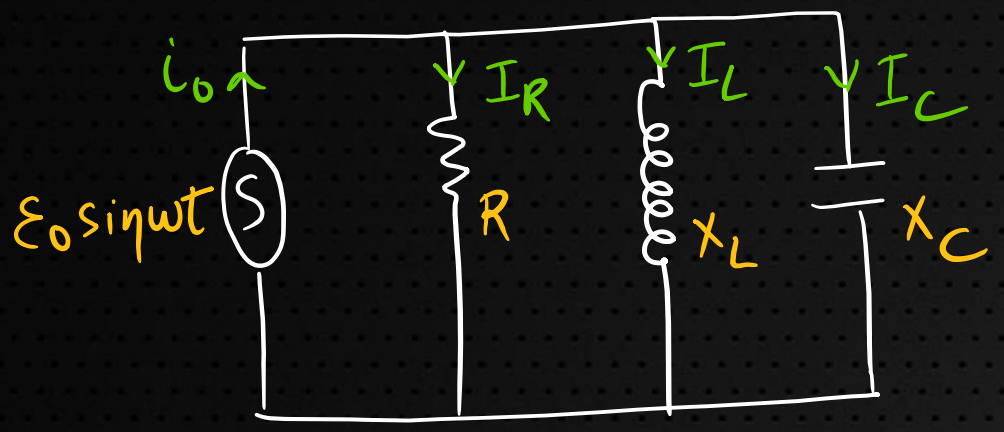
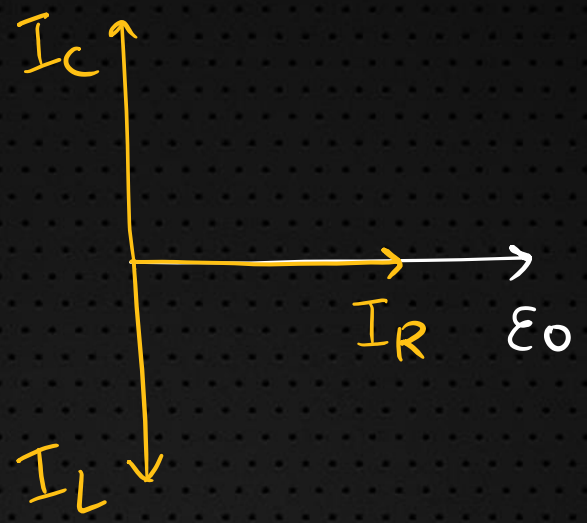
10. RLC (PARALLEL)





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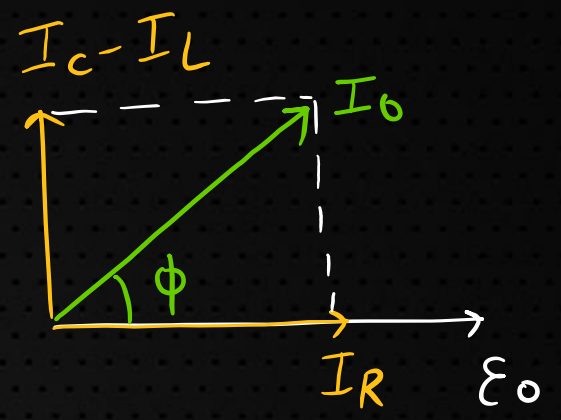

(a) $\tan\phi = \dfrac{I_C - I_L}{I_R}$

$$= \frac{\dfrac{\mathcal{E}_0}{X_C} - \dfrac{\mathcal{E}_0}{X_L}}{\dfrac{\mathcal{E}_0}{R}}$$

(b) $I_0 = \sqrt{I_R^2 + (I_C - I_L)^2}$

$$\Rightarrow \frac{\mathcal{E}_0}{Z} = \sqrt{\left(\frac{\mathcal{E}_0}{R}\right)^2 + \left(\frac{\mathcal{E}_0}{X_C} - \frac{\mathcal{E}_0}{X_L}\right)^2}$$

$$\Rightarrow \frac{1}{Z} = \sqrt{\frac{1}{R^2} + \left(\frac{1}{X_C} - \frac{1}{X_L}\right)^2}$$

(c) $\omega_R = \dfrac{1}{\sqrt{LC}}$

(d) At ω_R, Z is max

$\Rightarrow i$ is min.

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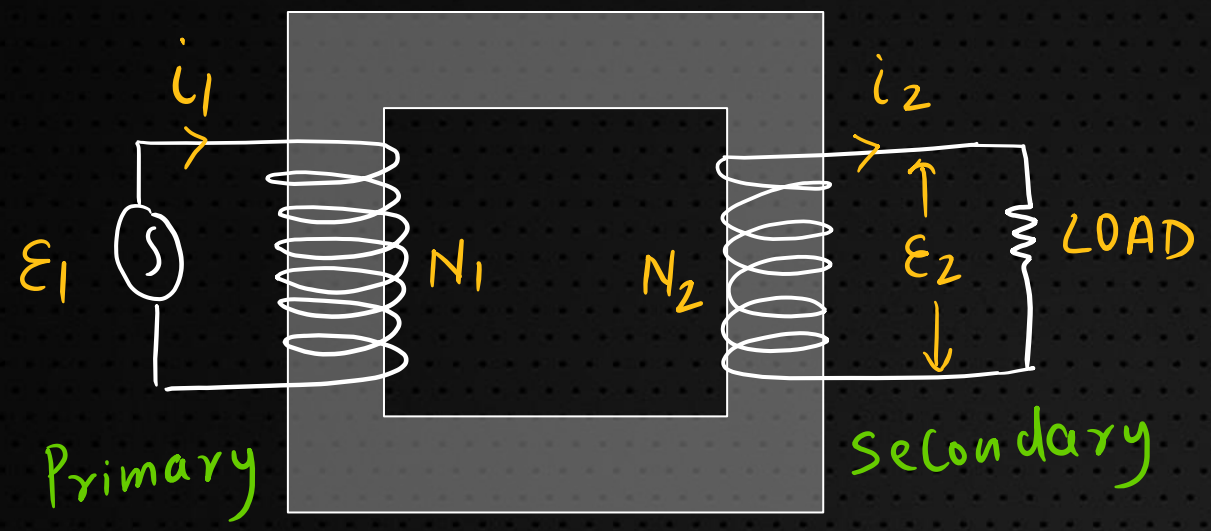
11. TRANSFORMER



N_1 and N_2 are number of turns.

(a) $\frac{\mathcal{E}_1}{\mathcal{E}_2} = \frac{N_1}{N_2}$

→ $N_1 > N_2 \Rightarrow \mathcal{E}_1 > \mathcal{E}_2$

(step down transformer)

→ $N_2 > N_1 \Rightarrow \mathcal{E}_2 > \mathcal{E}_1$

(step up transformer)

(b) For ideal transformer

(No losses)

$$\mathcal{E}_1 i_1 = \mathcal{E}_2 i_2$$

(c) LOSSES

→ Cu loss (Joules heating)

→ Eddy current

(Heat due to it)

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