AC Circuits

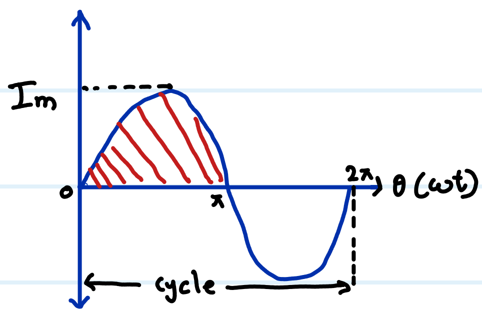
AC Fundamentals → R-L-C

Series Circuits → RC / RL / LCR

- Eqn of sinusoidal AC waveform

$$I = I_m \sin\theta$$

- Average value of sinusoidal waveform:



$$\boxed{\text{Avg. value} = \frac{\text{Area of half cycle}}{\text{Base length of half cycle}}}$$

$$\therefore I_{avg} = \frac{\int_0^{\pi} I\, d\theta}{\pi} \qquad \because I = I_m \sin\theta$$

$$= \frac{\int_0^{\pi} I_m \sin\theta\, d\theta}{\pi}$$

$$= \frac{I_m}{\pi} \int_0^{\pi} \sin\theta\, d\theta$$

$$= \frac{I_m}{\pi} \left[-\cos\theta\right]_0^{\pi}$$

$$= \frac{I_m}{\pi} \left[-(-1) - (-1)\right]$$

$$I_{avg} = \frac{I_m}{\pi}\left[1+1\right] = \frac{2I_m}{\pi}$$

$$\therefore \boxed{I_{avg} = \frac{2I_m}{\pi} = 0.637 I_m}$$

- RMS value

$\cos 2\theta = 1 - 2\sin^2\theta$

$\sin^2\theta = \frac{1-\cos 2\theta}{2}$

$$I_{RMS} = \sqrt{\frac{\int_0^\pi I^2\, d\theta}{\pi}} = \sqrt{\frac{\int_0^\pi I_m^2 \sin^2\theta\, d\theta}{\pi}} = \sqrt{\frac{I_m^2}{\pi}\int_0^\pi \sin^2\theta\, d\theta}$$

$$= \sqrt{\frac{I_m^2}{\pi}\int_0^\pi \left(\frac{1-\cos 2\theta}{2}\right) d\theta} = \sqrt{\frac{I_m^2}{2\pi}\int_0^\pi (1-\cos 2\theta)\, d\theta}$$

$$= \sqrt{\frac{I_m^2}{2\pi}\left(\theta - \frac{\sin 2\theta}{2}\right)_0^\pi}$$

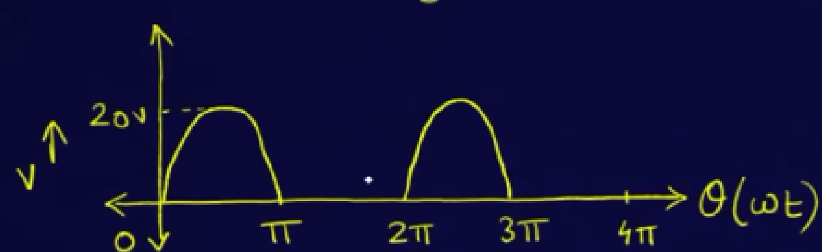
$$= \sqrt{\frac{I_m^2}{2\pi}(\pi - 0)}$$

$$= \sqrt{\frac{I_m^2 \pi}{2\pi}}$$

$$\therefore \boxed{I_{RMS} = \frac{I_m}{\sqrt{2}} = 0.707 I_m}$$

$$\boxed{V_{rms} = \sqrt{\frac{\text{Area of full cycle}}{\text{Base length}}}}$$

Q ① Find the average value of waveform



→

$I = I_m \sin\theta$

$V = V_m \sin\theta$

Equation	Interval
1) $V = 20\sin\theta$	$0 < \theta < \pi$
2) $V = 0$	$\pi < \theta < 2\pi$

$$V_{avg} = \frac{\text{Area of full cycle}}{\text{Base length of full cycle}} = \frac{\int_0^{2\pi} v\,d\theta}{2\pi}$$

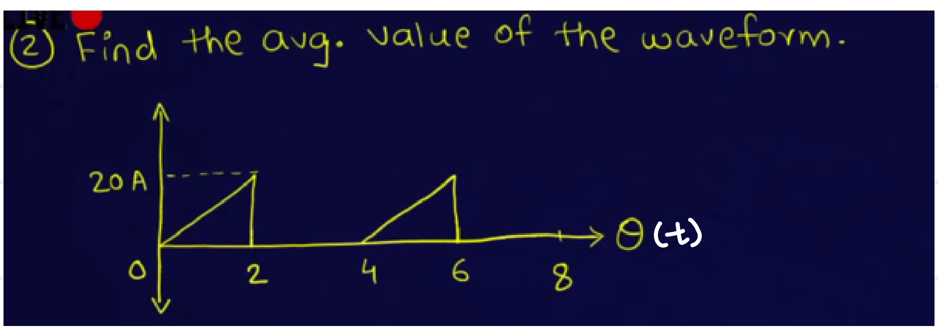
$$= \frac{1}{2\pi}\left[\int_0^{\pi} 20\sin\theta\,d\theta + \int_{\pi}^{2\pi} 0\,d\theta\right] \quad 0$$

$$= \frac{10}{\pi}\left[-\cos\theta\right]_0^{\pi} = \frac{10}{\pi}\left[-\cos\pi - (-\cos 0)\right] = \frac{10}{\pi}\left[-(-1) - (-1)\right]$$

$$= \frac{10}{\pi}\left[1+1\right] = \frac{20}{\pi}$$

$\therefore V_{avg} = 6.366\ V$

Q]



$y = mx$

$(y_2 - y_1) = m(x_2 - x_1)$

$\therefore m = \frac{y_2 - y_1}{x_2 - x_1} = \frac{20-0}{2-0} = 10$

→

Equation	Interval
1) $I = mt = 10t$	$0 < t < 2$
2) $i = 0$	$2 < t < 4$

$$I_{avg} = \frac{\int_0^4 I\,dt}{4}$$

$$= \frac{1}{4}\left[\int_0^2 10\,dt + \int_2^4 0\,dt\right]$$

$$= \frac{10}{4}\left[\frac{t^2}{2}\right]_0^2 + 0$$

$$= \frac{10}{8}\left(2^2 - 0^2\right)$$

$$\therefore I_{avg} = 5A$$

* Some important formula :-

$$\omega = 2\pi f = \frac{2\pi}{T}$$

$$I_{RMS} = \frac{I_m}{\sqrt{2}}, \quad V_{rms} = \frac{V_m}{\sqrt{2}}$$

$$I_{avg} = 0.637\, I_m$$

$$\text{Form Factor} = \frac{I_{rms}}{I_{avg}}$$

* Algebra of Phasor

① Length of Phasor : $V = \frac{V_m}{\sqrt{2}}$

② Rectangular Form / Cartesian form . $x + iy = x + jy$

③ Polar form : $r\angle\theta = [r(\cos\theta + i\sin\theta)]$

- Rectangular form :

$Z_1 = x_1 + iy_1$, $Z_2 = x_2 + iy_2$

① $Z_1 + Z_2 = (x_1 + iy_1) + (x_2 + iy_2)$

$= (x_1 + x_2) + i(y_1 + y_2)$ .... (Addition)

② $Z_1 - Z_2 = (x_1 + iy_1) - (x_2 + iy_2)$

$= (x_1 - x_2) + i(y_1 - y_2)$ .... (Subtraction)

- Polar Form

① $z_1 = r_1\angle\theta_1$, $z_2 = r_2\angle\theta_2$

$(z_1 . z_2) = (r_1\angle\theta_1).(r_2\angle\theta_2)$

$= (r_1 . r_2)\angle(\theta_1 + \theta_2)$ .... (Multiplication)

② $\frac{Z_1}{Z_2} = \frac{r_1\angle\theta_1}{r_2\angle\theta_2} = \frac{r_1}{r_2}\angle(\theta_1 - \theta_2)$ .... (Division)

- Phasor Numericals

Q) LIVE

① Find the resultant of the following voltages,

$V_1 = 25 \sin \omega t$, $V_2 = 10 \sin\left(\omega t + \frac{\pi}{6}\right)$

$V_3 = 30 \cos \omega t$, $V_4 = 20 \sin\left(\omega t - \frac{\pi}{4}\right)$

→

$V_1 = 25 \sin \omega t$, $V_2 = 10 \sin(\omega t + \pi/6)$

$V_3 = 30 \sin\left(\omega t + \frac{\pi}{2}\right)$, $V_4 = 20 \sin\left(\omega t - \frac{\pi}{4}\right)$

∴ Converting the standard sine waveform,

$\bar{V}_1 = \frac{V_m}{\sqrt{2}} \angle \phi_1 = \frac{25}{\sqrt{2}} \angle 0 = (17.68 \angle 0)$

$\bar{V}_2 = \frac{10}{\sqrt{2}} \angle \phi_2 = (7.07 \angle 30°)$

$\bar{V}_3 = \frac{30}{\sqrt{2}} \angle \phi_3 = (21.22 \angle 90°)$

$\bar{V}_4 = \frac{20}{\sqrt{2}} \angle \phi_4 = (14.14 \angle -45°)$

Polar form.

∴ For resultant voltage,

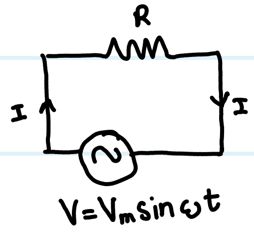
$V = \bar{V}_1 + \bar{V}_2 + \bar{V}_3 + \bar{V}_4$

$= (17.68 \angle 0) + (7.07 \angle 30) + (21.21 \angle 90) + (14.14 \angle -45)$

$\bar{V} = (33.80 + i(14.75))\ V$ → (Rectangular)

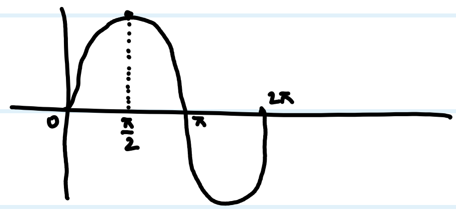
$\bar{V} = (36.88 \angle 23.58)\ V$ → (Polar)

* Resistive Circuit:



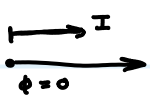
According to Ohm's Law,

$$I = \frac{V}{R} = \frac{V_m \sin\omega t}{R}$$



For maximum, $\sin\omega t = 1$

$$\therefore \boxed{I = \frac{V_m}{R}}$$



$\therefore$ Instantaneous Power $= P = V \times i$

$$= (V_m \sin\omega t)(I_m \sin\omega t)$$

$$= V_m I_m . \sin^2\omega t$$

$$= V_m I_m \left(\frac{1 - \cos 2\omega t}{2}\right)$$

$$\boxed{P = \frac{V_m I_m}{2} - \frac{V_m I_m \cos 2\omega t}{2}}$$

$\therefore$ Power Consumed $= P = \frac{1}{2\pi}\int_0^{2\pi} P \, d\omega t$

$$= \frac{1}{2\pi}\int_0^{2\pi}\left[\frac{V_m I_m}{2} - \frac{V_m I_m \cos 2\omega t}{2}\right] d\omega t$$

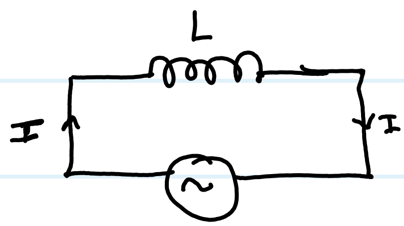
$$= \frac{1}{2\pi}\left[\frac{V_m I_m}{2}\int_0^{2\pi} d\omega t - \frac{V_m I_m}{2}\int_0^{2\pi} \cos 2\omega t\, dt\right]$$

$$= \frac{V_m I_m}{4\pi}\left[(\omega t)_0^{2\pi} - \left(\frac{\sin 2\omega t}{2}\right)_0^{2\pi}\right]$$

$$= \frac{V_m I_m}{4\pi}\left[(2\pi - 0) - 0\right] = \frac{V_m I_m}{2} = \frac{V_m}{\sqrt{2}} \cdot \frac{I_m}{\sqrt{2}}$$

$$\boxed{P = \frac{V_m}{\sqrt{2}} \cdot \frac{I_m}{\sqrt{2}}}$$

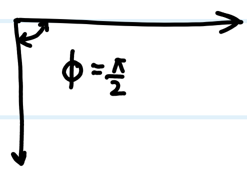
* Pure Inductive Circuit :



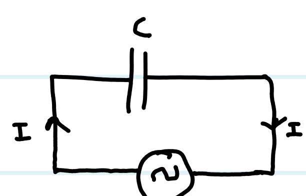
$V = V_m \sin \omega t$

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

Current lagging behind the voltage by 90°

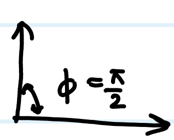


* Pure Capacitive Circuit:



$V = V_m \sin \omega t$

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



Current leads voltage by 90°.

* Pure L circuit :

- Opposition to circuit (Z):

$$I_m = \frac{V_m}{\omega L} \qquad \therefore \frac{V_m}{I_m} = \omega L$$

Dividing both numerator & denominator by $\sqrt{2}$,

$$\therefore \frac{V_m/\sqrt{2}}{I_m/\sqrt{2}} = \omega L \qquad \therefore \frac{V}{I} = \omega L$$

$$\therefore Z = \omega L$$

$$\therefore Z = 2\pi f L$$

$\therefore X_L = 2\pi f L$ = Inductive Reactance

* Pure C circuit

- Opposition to current : (Z)

$$\frac{I_m}{V_m} = \omega C$$

$$\therefore \frac{V_m}{I_m} = \frac{1}{\omega C}$$

$\therefore$ Dividing Nr. & Dr. by $\sqrt{2}$,

$$\therefore \frac{V_m/\sqrt{2}}{I_m/\sqrt{2}} = \frac{1}{\omega C}$$

$$\therefore \frac{V}{I} = \frac{1}{\omega C}$$

$$\therefore Z = \frac{1}{\omega C}$$

$\therefore X_C = \frac{1}{\omega C} = \frac{1}{2\pi f C}$ = Capacitive Reactance

Q

(1) A 318 μF Capacitor is connected across a 230 V, 50 Hz Supply. Determine (1) Capacitive reactance.
(2) rms value of current
(3) equation for vtg. & current.

$\rightarrow$ $C = 318 = 318 \times 10^{-6}$

$V = 230\,V \quad , \quad f = 50\,Hz$

$\omega = 2\pi f = 100\pi$

(1) $X_c = \dfrac{1}{\omega C} = \dfrac{1}{100\pi \times 318 \times 10^{-6}} = 10\,\Omega$

(2) $I_{rms} = \dfrac{V_m}{X_c} = \dfrac{230}{10} = 23\,V$

(3) $V = \dfrac{V_m}{\sqrt{2}} \quad \therefore V_m = \sqrt{2}V = \sqrt{2} \times 230 = 325.27\,V$

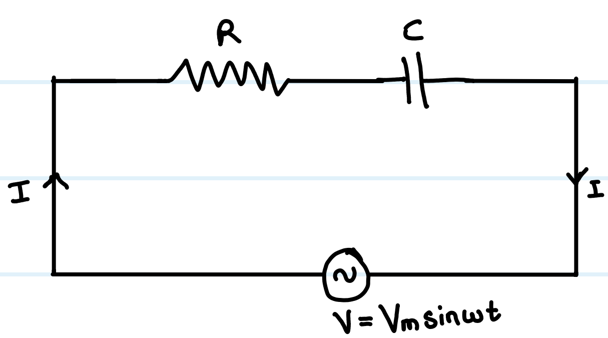
$I = \dfrac{I_m}{\sqrt{2}} \quad : \quad I_m = \sqrt{2}I = \sqrt{2} \times 23 = 32.53\,A$

$V = V_m \sin \omega t = 325.27 \sin(314t)$

$I = I_m \sin\left(\omega t + \frac{\pi}{2}\right) = 32.53 \sin\left(314t + \frac{\pi}{2}\right)$

* Series R-C circuit :

(1) $V_R = IR \; , \; V_c = IX_c \; , \; V = IZ$



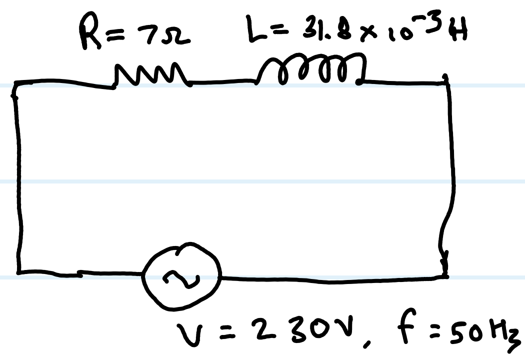
(2) Power factor $= \cos\phi$

where, $\phi = \tan^{-1}\left(\dfrac{V_c}{V_R}\right) = \tan^{-1}\left(\dfrac{X_c}{R}\right)$

(3) Impedence : $Z = \sqrt{R^2 + X_c^2} \; , \; \bar{Z} = R - iX_c \; , \; Z\angle -\phi$

Q]

① A coil having a resistance of 7 Ω and an inductance of 31.8 mH is connected to 230 V, 50 Hz supply. Calculate ① circuit current ② phase angle ③ power factor ④ Power consumed.



→ ① $\omega = 2\pi f = 314.15$

$X_L = \omega L \approx 10\,\Omega$

$Z = \sqrt{R^2 + X_L^2} = \sqrt{7^2 + 10^2}$

$Z = 12.21\,\Omega$

$I = \frac{V_m}{Z} = \frac{230}{12.20} = 18.84\ A$

② Phase angle $\phi = \tan^{-1}\left(\frac{X_L}{R}\right)$

$\phi = 55°$

③ Power factor $= \cos\phi$

$= \cos(55°)$

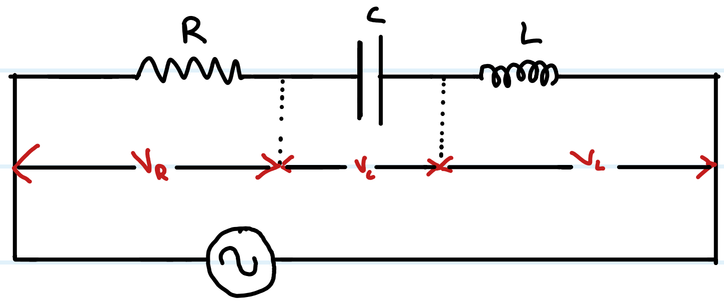
$= 0.574$ (lagging)

④ $P = VI\cos\phi$

$= 230 \times 18.84 \times 0.574$

$P = 2487.26\ W$

* Series L-C-R circuits :



According to ohm's Law

$$V = IZ$$

$$V_R = IR, \quad V_L = IX_L, \quad V_C = IX_C$$

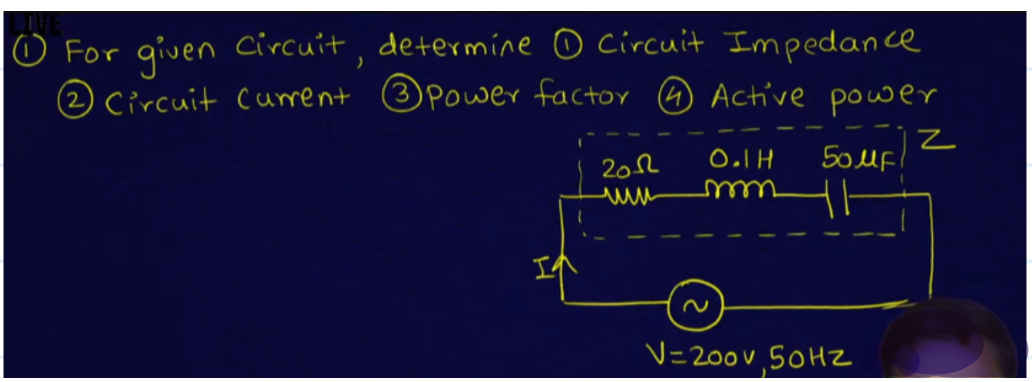
Phase Angle $\phi = \tan^{-1}\left(\frac{V_L - V_C}{V_R}\right) = \tan^{-1}\left(\frac{IX_L - IX_C}{IR}\right) = \tan^{-1}\left(\frac{X_L - X_C}{R}\right)$

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

$$\bar{Z} = \left[R + i(X_L - X_C)\right]$$

$$Z = (\bar{Z} \angle \phi)$$

Q



→ $\omega = 2\pi f = 314$

$$X_L = \omega L = 314 \times 0.1 = 31.42\ \Omega$$

$$X_C = \frac{1}{\omega C} = \frac{1}{314 \times 50 \times 10^{-6}} = 63.66\ \Omega$$

$$Z = \sqrt{(X_L - X_C)^2 + R^2} = \sqrt{(63.7 - 31.4)^2 + 20^2} = 37.94$$

$$\phi = \tan^{-1}\left(\frac{X_L - X_C}{R}\right) = \tan^{-1}\left(\frac{32.24}{20}\right) = 58.19^\circ$$

$$I = \frac{V}{Z} = \frac{200}{37.94} = 5.27$$

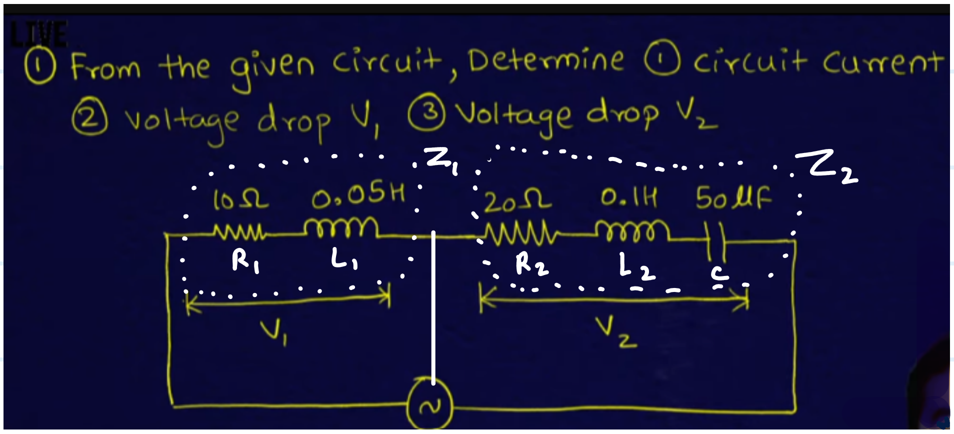
Power factor $= \cos\phi = \cos(58.19^\circ) = 0.527$ (lag)

Active Power : $P = VI\cos\phi$

$$= (200)(5.27)(0.527)$$

$$P = 555.46\,W$$

Q)



→ Taking applied voltage as ref.

$\bar{V} = 200 \angle 0$, $R = 10 + 20 = 30$

$L_1 = 0.05H$, $X_{L_1} = 2\pi f L_1 = 2\pi(50)(0.05) = 15.71\,\Omega$

$L_2 = 0.1H$, $X_{L_2} = 2\pi f L_2 = 2\pi(50)(0.1) = 31.42\,\Omega$

$\therefore X_L = X_{L_1} + X_{L_2} = 15.71 + 31.42 = 47.13\,\Omega$

$C = 50 \times 10^{-6}F$, $X_C = \frac{1}{2\pi f C} = \frac{1}{2\pi(50)(50\times10^{-6})} = 63.66\,\Omega$

Net resonance $= X_c - X_L = 63.66 - 47.13 = 16.53\ \Omega$

$\therefore$ Total Impedance of circuit,

$$Z = \sqrt{(30)^2 + (16.53)^2} = 34.25\ \Omega$$

$$I = \frac{200}{34.25} = 5.84$$

$$Z_1 = \sqrt{10^2 + (15.71)^2} = 18.62\ \Omega$$

$$Z_2 = \sqrt{(20)^2 + (63.66 - 31.42)^2} = 37.94\ \Omega$$

For Voltage drops,

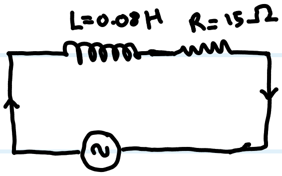
$$V_1 = IZ_1 = (5.84)(18.62) = 108.74\ V$$

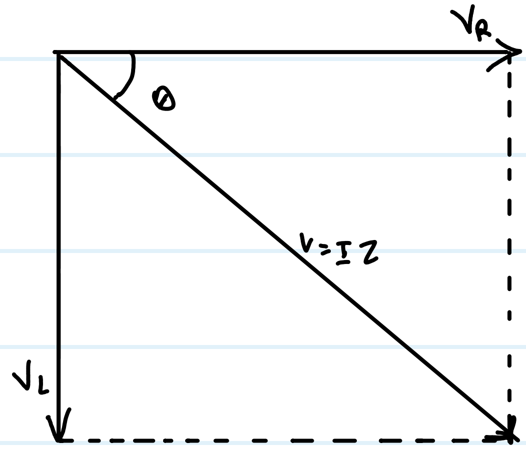
$$V_2 = IZ_2 = (5.84)(37.94) = 221.57\ V$$

2018

Q5a) → $L = 0.08 H$

$R = 15 \Omega$





$V = 240V$, $f = 50Hz$.

→ $X_L = 2\pi f L = 100 \times 3.14 \times 0.08$

$X_L = 25.12 \Omega$

$Z = \sqrt{R^2 + X_L^2} = 29.26$

$I = \frac{V_m}{Z} = 8.20 \text{ A}$

Phase angle : $\tan^{-1}\left(\frac{X_L}{R}\right) = 59.16$

Power factor : $\cos\phi = 0.51$

$P = VI\cos\phi = (240)(8.20)(0.51) = 1003.68 W$

$V_R = IR = (8.20)(15) = 123 V$

$V_L = IX_L = (8.20)(25.12) = 206 V$

Q

$\rightarrow$ $\bar{V} = 100 \angle 0° \, V$

$\bar{Z}_1 = 20 \angle 30° \, \Omega$

$\bar{V}_1 = 40 \angle -30° \, \Omega$

$$I = \frac{\bar{V}_1}{\bar{Z}_1} = \frac{40 \angle -30°}{20 \angle 30°} = 2 \angle -60° A$$

$$\bar{Z} = \frac{\bar{V}}{\bar{I}} = \frac{100 \angle 0°}{2 \angle -60°} = 50 \angle 60° = 25 + j43.3 \, \Omega$$

$\bar{Z}_1 = 20 \angle 30° = 17.32 - j10 \, \Omega$

$\bar{Z} = \bar{Z}_1 + \bar{Z}_2$

$\bar{Z}_2 = \bar{Z} - \bar{Z}_1 = 7.68 + j33.3 \, \Omega$

Reactive component of $\bar{Z}_2 = 33.3 \, \Omega$

Q

$\rightarrow$ $V = 120V$, $P = 1200W$, $i(t) = 28.3 \, (314t - \phi)$

Resistance,

$$I = \frac{28}{\sqrt{2}} = 20.01 \, A$$

$P = VI\cos\phi \Rightarrow 1200 = 120 \times 20.01 \times \cos\phi$

$\cos\phi = 0.499 \Rightarrow \phi = 60.02°$

$$Z = \frac{V}{I} = \frac{120}{20.01} = 6 \, \Omega$$

$\bar{Z} = Z \angle \phi = 6 \angle 60.02°$

$\bar{Z} = 3 + j5.2 \, \Omega$

$R = 3 \, \Omega$

Inductance,

$X_L = 5.2 \, \Omega$

$X_L = \omega L \Rightarrow 5.2 = 3.14 \times L$

$L = 0.0165 H$

Q) $V = 120\angle 30^\circ V$, $f = 50Hz$

$i = 3\angle -15^\circ A$

$\overline{Z}_1 = 10 + j48.3 \ \Omega$

$\rightarrow \overline{Z} = \dfrac{\overline{V}}{\overline{I}} = \dfrac{120 \angle 30^\circ}{3 \angle -15^\circ} = 40\angle 45^\circ = 28.28 + j2828 \ \Omega$

$\overline{Z} = \overline{Z}_1 + \overline{Z}_2$

$\overline{Z}_2 = \overline{Z} - \overline{Z}_1 = (10 + j48.3) - (28.28 + j28.28) = 18.28 - j20.02\Omega$

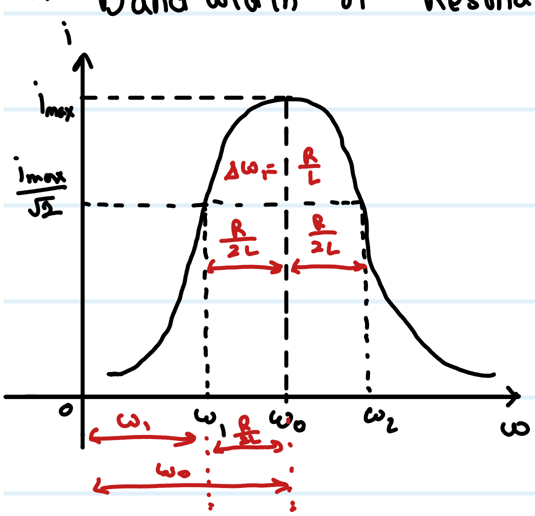
$\overline{Z}_1 = 10 + 48.3j = R + X_L j$

$X_L = 48.3 = 2\pi f L$

$\therefore L = 0.1537 H$

Similarly, $C = 159 \mu F$

* Band width of Resonant circuit with Q factor:



$\Delta\omega = \omega_2 - \omega_1 = \dfrac{R}{L}$

$\omega_1 = \omega_0 - \dfrac{R}{2L}$ $\qquad$ $\omega_2 = \omega_0 + \dfrac{R}{2L}$

$2\pi f_1 = 2\pi f_0 - \dfrac{R}{2L}$ $\qquad$ $2\pi f_2 = 2\pi f_0 + \dfrac{R}{2L}$

$\boxed{f_1 = f_0 - \dfrac{4}{4\pi L}}$ $\qquad$ $\boxed{f_2 = f_0 + \dfrac{R}{4\pi L}}$

for good tuning (good quality of audio/video)

$X_C = X_L$

TV, Radio, Mobile Phones

① Sharpness of curve ↑

② $\Delta\omega$ ↓

③ Resonance ↑

④ R ↓

⑤ i ↑

⑥ L ↓

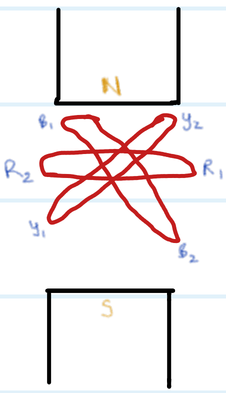
$$Q_{factor} = \frac{\omega_0}{\Delta\omega} = \frac{\frac{1}{\sqrt{LC}}}{R/L}$$

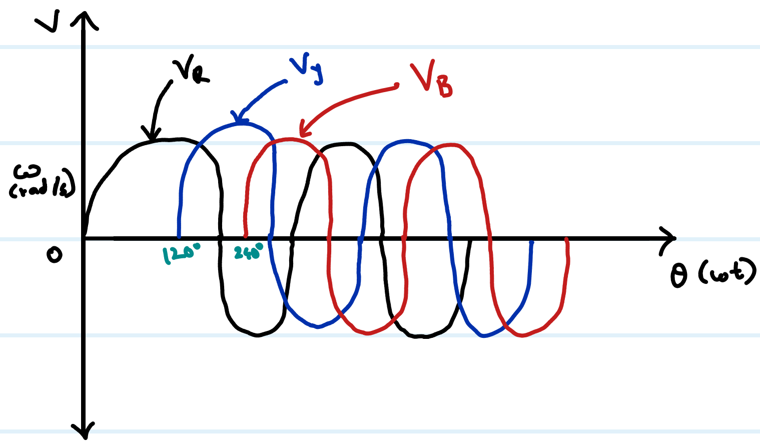
$$\therefore \; Q_{factor} = \frac{1}{R}\sqrt{\frac{L}{C}}$$

* Choke Coil

Three-Phased AC circuits

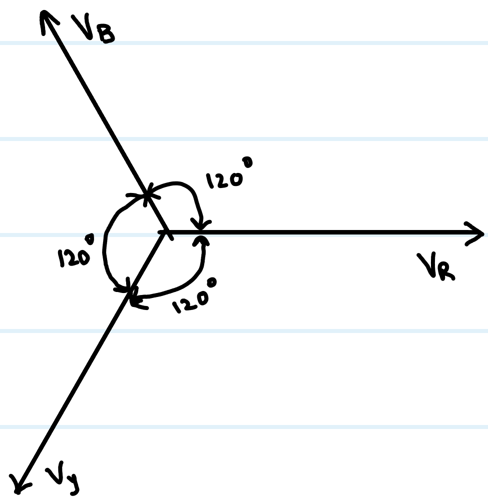
* Generation of Three phase:





* Eqns of voltages of 3φ circuits:

- $V_R = V_m \sin \omega t$
- $V_y = V_m \sin (\omega t - 120°)$
- $V_B = V_m \sin (\omega t - 240°)$



Phase Sequence The sequence in which the voltages in the three phases reach the maximum positive value is called the phase sequence or phase order. From the phasor diagram of a three-phase system, it is clear that the voltage in the coil R attains maximum positive value first, next in the coil Y and then in the coil B. Hence, the phase sequence is R - Y - B

Phase Voltage The voltage induced in each winding is called the phase voltage.

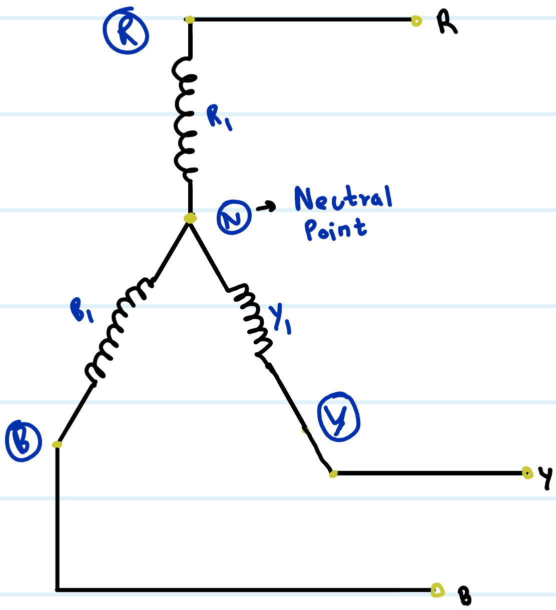
Phase Current The current flowing through each winding is called the phase current.

line voltage.

Line Voltage The voltage available between any pair of terminals or lines is called

Line Current The current flowing through each line is called the line current.

* Star Connections :



$i_R = I_m \sin \omega t$

$i_y = I_m \sin(\omega t - 120°)$

$i_B = I_m \sin(\omega t - 240°)$

• Line Voltage :

V_L = line voltage

V_{ph} = Phase voltage

$V_L = \sqrt{3}\, V_{ph}$

• Power :

Total power = P = 3 x power in each phase

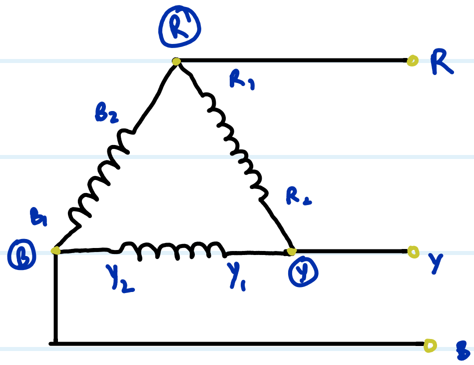
$\therefore P = 3 \times V_{ph} \times I_{ph} \times \cos\phi$

$\therefore P = V_{ph} I_{ph} \cos\phi$

∴ For star connection,

$\therefore P = \sqrt{3}\, V_L I_L \cos\phi$

* Delta Connection :



Star → series
delta → Parallel

∵ Phase Voltage $= V_{ph} = V_L$

- Line Current : $I_L = \sqrt{3}\, I_{ph}$

- Power = 3 x power in each phase

  $= 3 \times V_{ph}\, I_{ph} \cos\phi$

$\therefore P = \sqrt{3}\, V_L I_L \cos\phi$

Star Connection	Delta Connection
① $V_L = \sqrt{3}\, V_{ph}$	① $V_L = V_{ph}$
② $I_L = I_{ph}$	② $I_L = \sqrt{3}\, I_{ph}$
③ $P = \sqrt{3}\, V_L I_L \cos\phi$	③ $P = \sqrt{3}\, V_L I_L \cos\phi$
④ Line vtg. leads the respective phase voltage by 30°	④ Line current lags behind I_{ph} by 30°

Q LIVE
① Three similar coils, each of resistance 8 Ω and induct. 0.02 H, are connected in star across a 3ϕ, 50 Hz, 230 V supply. Calculate the line current, total power. (2019)

→ $R_{ph} = 8\,\Omega$, $L = 0.02\,H$, $X_L = 2\pi f L = 2\pi(50)(0.02) = 6.28\,\Omega$

∴ $V_L = 230\,V$ & $f = 50\,Hz$

∴ For star connection,

∴ $V_{ph} = \frac{230}{\sqrt{3}} = 132.79\,V$

∴ $Z_{ph} = R + jXL$

$= (8 + j\,6.28)$ ... Rect

$= (10.17\,\angle\,38.13)$ polar

∴ $Z_{ph} = 10.17$, $\phi = 38.13$

∴ By Ohm's Law,

∴ $\frac{V_{ph}}{Z_{ph}} = \frac{137.29}{10.1} = 13.06\,A$

∴ Line current : $I_L = I_{ph}$

∴ $I_L = 13.06$

∴ Power in circuits,

$P = \sqrt{3}\,V_L I_L \cos\phi$

$P = 4092\,W$

or

$P = 4.092\,KW$