ELECTRICAL COMPUTER MECHATRONICS

تقدم لجنة ElCoM الاكاديمية

دوسية لمادة:

دوائر كهربائية (2)

جزيل الشكر للطالبة:

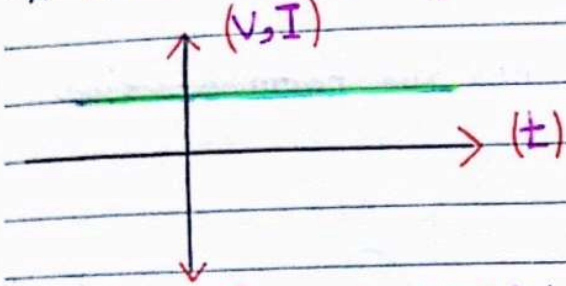
سجى البزايعة

Circuit "2"

CH 1:- "Sinusoidal steady state analysis":-

_ Firstly we need to remember the Following which we studied in (circuit "1") :-

* DC circuits :- (Direct current circuits)



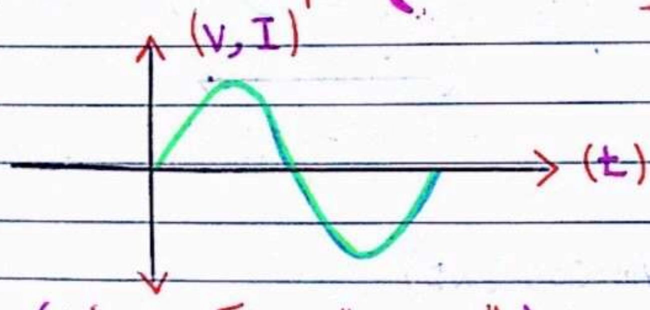
⇐ وهي عبارة عن دوائر كهربائية فيها (التيار والجهد الكهربائي) لا يتغيران مع مرور الزمن ، (مقدارًا واتجاهًا).

⇒ (L و C) are disconnected.

- Inductor (L) ⟶ short circuit (S.C).
- Capacitor (C) ⟶ open circuit (O.C).

_ Now in (circuit "2") we will study :-

* AC circuits :- (Alternating current circuits)



⇐ وهي عبارة عن دوائر كهربائية فيها (التيار والجهد الكهربائي) يتغيران مع مرور الزمن ، (مقدارًا واتجاهًا).

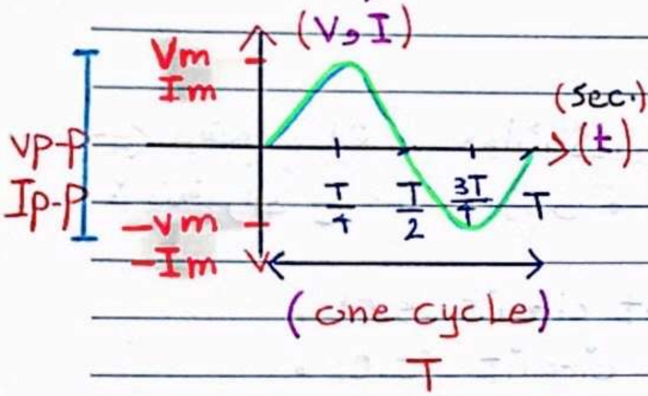
⇒ (L و C) are connected.

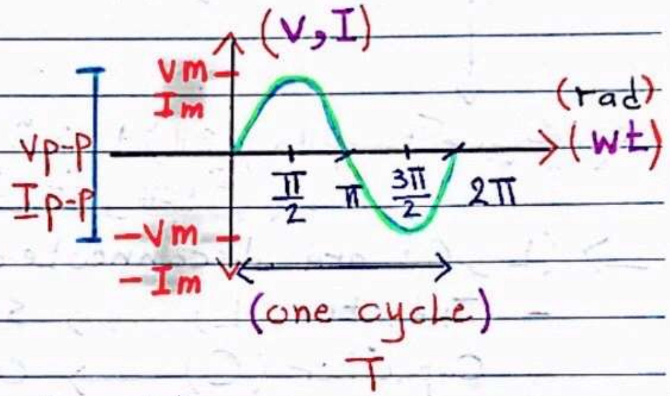
إعداد:-م.سجى البزايعه

- In (Ac circuits) there are many Forms For the waves :-
  1- sinusoidal waves.
  2- square waves.
  3- triangular waves.

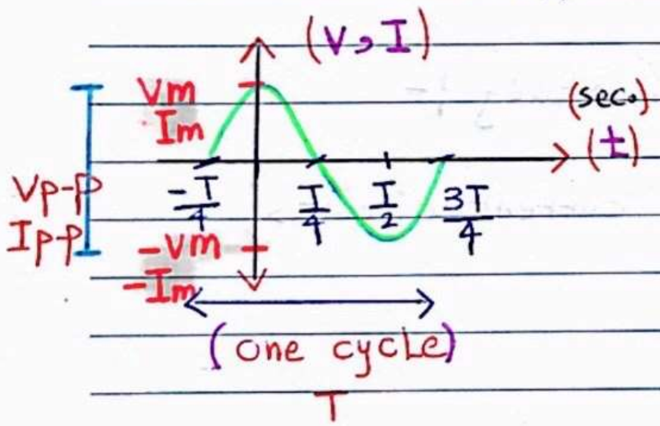
=> In (circuit "2") we will Focus on (sinusoidal waves).

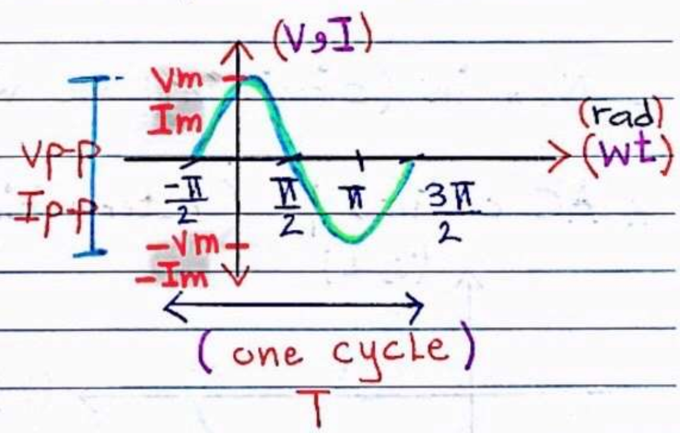
* Sinusoid :- Is a signal that has the Form of (sine or cosine) Function.





$$v(t) = V_m \sin(wt)$$





$$v(t) = v_m \cos(wt)$$

1- T :- Time (The period which is required to complete one cycle) و Second (S).
وهي المدة الزمنية التي تحتاجها الدورة لتعيد نفسها

2- F :- Frequency (The number of cycles per unit time) و HerZ (HZ) . التكرار

$$F = \frac{1}{T} \quad .... \boxed{1}$$

3- W :- Angular Frequency و (rad/sec.) . التردد الزاوي

$$W = 2\pi F = \frac{2\pi}{T} \quad .... \boxed{2}$$

4- Vm :- Amplitude (A) = Vpeak (Vp) و Volt (V).

$$A = V_m = V_p \quad .... \boxed{3}$$

5- Im :- Amplitude (A) = I peak (Ip) و Ampere (A).

$$A = I_m = I_p \quad .... \boxed{4}$$

6- Vp-p :- V peak to peak. من القمة إلى القاع (القمة)

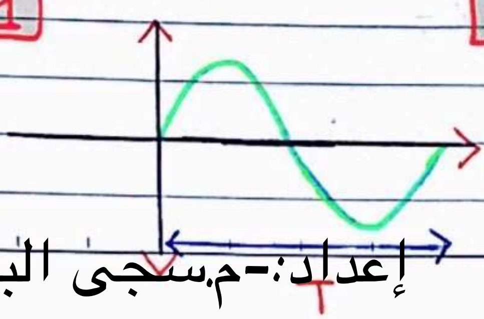
$$V_{p-p} = 2V_m = 2V_p \quad .... \boxed{5}$$

7- Ip-p :- I peak to peak. من القمة إلى القاع (القمة)

$$I_{p-p} = 2I_m = 2I_p \quad .... \boxed{6}$$

⟹ For these three waves, Find the relationship between Frequencies and Times :-

1



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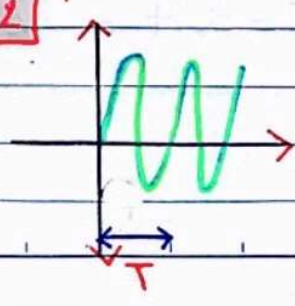
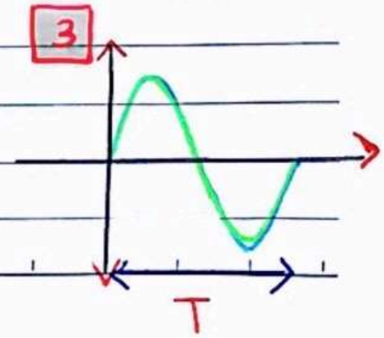


3



$\Rightarrow$ $T_1 > T_3 > T_2$

وبما أن :- $T = \frac{1}{F}$ / $T \propto \frac{1}{F}$ (علاقة عكسية)

so :- $F_2 > F_3 > F_1$

Q :- IF $v(t) = 200 \sin(2\pi t)$, Find :-

a) The Amplitude.

b) period.

c) Frequency.

d) Angular Frequency.

a) $V_m = V_p = A = 200V$.

b) $T = ?$! $\rightarrow$ $T = \frac{1}{F} = \frac{1}{1} = 1$ (sec).

c) $F = ?$! $\rightarrow$ $F = \frac{W}{2\pi} = \frac{\cancel{2\pi}}{\cancel{2\pi}} = 1$ (HZ).

d) $W = 2\pi$ (rad/s).

$\Rightarrow$ phase shift (β) :- زاوية الطور / زاوية الإزاحة $\Leftarrow$

- $+\beta \rightarrow$ إزاحة لليسار
- $-\beta \rightarrow$ إزاحة لليمين

وهي تمثل مقدار إزاحة الموجة الأصلية عن نقطة بدايتها قبل تعرضها للإزاحة.

$\therefore$ Note :-

$$\text{Angle in degree} = \frac{180}{\pi} \times \text{Angle in radian}.$$

$\pi = 3.14 = 22/7$.

إعداد:-م.سجى البزايعه

Q :- Given the sinusoidal voltage , $V(t) = 12\cos(50t + 10^\circ)\,V$

Find :- a) Amplitude.
b) phase shift.
c) Angular Frequency
d) period.
e) Frequency.
f) V(t) at t = 10 ms.

a) $V_m = V_p = A = 12$ volt.

b) $\phi = 10^\circ$.

c) $W = 50$ (rad/sec.).

d) $T = 2\pi F = \frac{2\pi}{W} = \frac{2\pi}{50} = 0.1256$ (sec).

e) $F = \frac{W}{2\pi} = \frac{50}{2\pi} = 7.957$ (HZ).

or $F = \frac{1}{T} = \frac{1}{0.1256} = 7.957$ (HZ).

f) $V(t) = 12\cos(\underbrace{50t}_{\text{rad}} + \underbrace{10^\circ}_{\text{degree}})\,V \Big|_{t = 10\,ms}$

$$\text{Angle in degree} = \frac{180}{\pi} \times \text{Angle in rad}$$

$$= \frac{180}{\pi} \times 50 = 2864.78^\circ.$$

So :-

$$V(10m) = 12\cos(2864.78^\circ \times 10 \times 10^{-3} + 10^\circ)$$
$$= 12\cos(38.6478^\circ)$$
$$= 9.37 \text{ volt}.$$

⟹ Lagging and Leading :-

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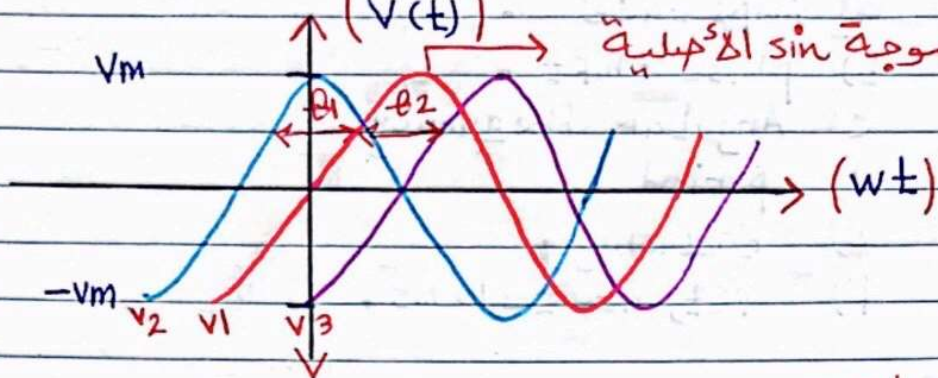
- In general :-



no phase shift

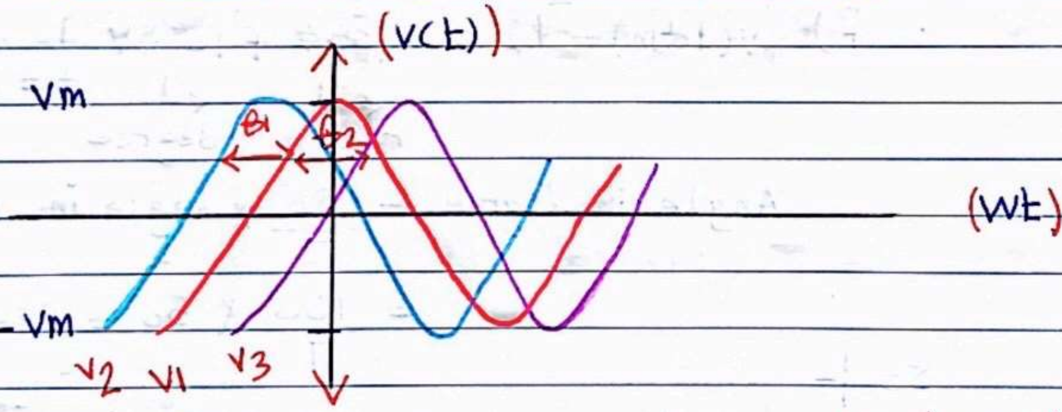
$V_1(t) = Vm \sin(wt) \longrightarrow [\theta = 0]$

متقدمة عن الموجة الأصلية $V_2(t) = Vm \sin(wt + \theta_1)$

متأخرة عن الموجة الأصلية $V_3(t) = Vm \sin(wt - \theta_2)$

So :-

- V_1 Lags V_2 ≡ V_2 Leads V_1 .
- V_1 Leads V_3 ≡ V_3 Lags V_1 .



no phase shift

$V_1(t) = Vm \cos(wt) \longrightarrow [\theta = 0]$

$V_2(t) = Vm \cos(wt + \theta_1)$

$V_3(t) = Vm \cos(wt - \theta_2)$

So :-

- V_1 Lags V_2 ≡ V_2 Leads V_1 .
- V_1 Leads V_3 ≡ V_3 Lags V_1 .

⇒ Two sinusoidal waves whose phases are to be compared must :-

1- Both be written as (sine waves or both as cosine waves).
2- Both be written with positive amplitudes.
3- Each have the same frequency.

so :- converting sines to cosines :-

$$\sin(wt) = \cos(wt - 90^\circ)$$
$$\cos(wt) = \sin(wt + 90^\circ)$$

∴ Note :-
The sine and cosine are essentially the same function, but with a 90° phase difference.

so :- converting from negative amplitudes to positive amplitudes :-

$$-\sin(wt) = \sin(wt \mp 180^\circ)$$
$$-\cos(wt) = \cos(wt \mp 180^\circ)$$

∴ Note :- If :-
- $v_1(t) = V_{m1} \sin(wt + \theta_1)$
- $v_2(t) = V_{m2} \sin(wt + \theta_2)$

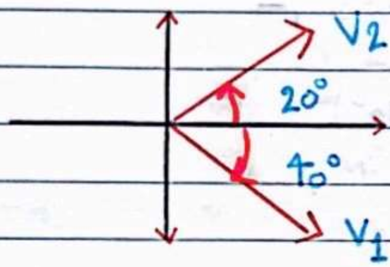
If :-
- $(\theta_1 = \theta_2) \longrightarrow (v_1, v_2)$ In phase.
- $(\theta_1 \neq \theta_2) \longrightarrow (v_1, v_2)$ out of phase. → (Leading and Lagging)

إعداد:-م.سجى البزايعه

Q 1- calculate the phase angle between :-

1- $v_1(t) = 12 \cos(120\pi t - 40^\circ)$.
$v_2(t) = 2.5 \cos(120\pi t + 20^\circ)$.

① same Frequency.
② +ve amplitude.
③ two waves are cosine.



الزاوية المحصورة بين المتجهين

- $\theta_1 = 20^\circ + 40^\circ = 60^\circ$
- $\theta_2 = 360^\circ - 60^\circ = 300^\circ$

دورة كاملة

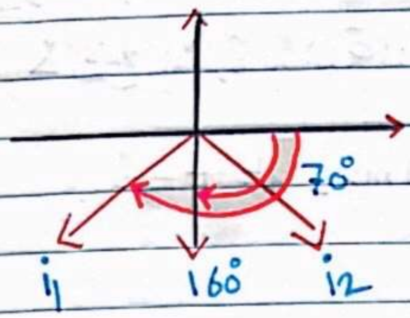
so :- 1- V_2 Leads V_1 by 60°.
2- V_1 Lags V_2 by 60°.
عكس ١ 3- V_2 Lags V_1 by 300°.
عكس ٢ 4- V_1 Leads V_2 by 300°.

∴ Note :-
لكي نميز مَن من المتجهين يسبق الآخر نقوم بتحريكهم عكس عقارب الساعة من يسبق الآخر يكون (Lead) والعكس.

2- $i_1(t) = 1.4 \sin(120\pi t - 70^\circ)$.
$i_2(t) = 0.8 \cos(120\pi t - 70^\circ)$.

① same Frequency.
② +ve amplitude.

so :- $i_1(t) = 1.4 \cos(120\pi t - 70^\circ - 90^\circ)$
$i_1(t) = 1.4 \cos(120\pi t - 160^\circ)$.



- $\theta_1 = 160° - 70° = 90°$
- $\theta_2 = 360° - 90° = 270°$

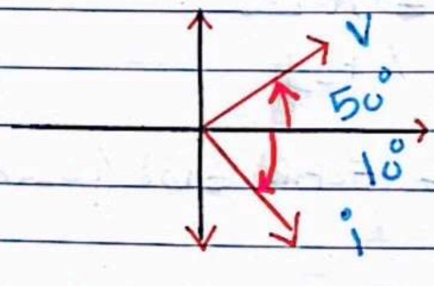
دورة كاملة

sol:- 1- i_2 Leads i_1 by 90°.
2- i_1 Leads i_2 by 90°.
عكس ١ ← 3- i_2 Lags i_1 by 270°.
عكس ٢ ← 4- i_1 Leads i_2 by 270°.

3- $v(t) = -4 \sin(100\pi t - 40°)$.
$i(t) = 10 \cos(100\pi t - 10°)$.

① same Frequency.

so :- 1 $v(t) = -4 \cos(100\pi t - 40° - 90°)$
$v(t) = -4 \cos(100\pi t - 130°)$
2 $v(t) = 4 \cos(100\pi t - 130° + 180°)$
$v(t) = 4 \cos(100\pi t + 50°)$



- $\theta_1 = 50° + 10° = 60°$.
- $\theta_2 = 360° - 60° = 300°$.

دورة كاملة

sol:- 1- V Leads i by 60°.
2- i Lags V by 60°.
عكس ١ ← 3- V Lags i by 300°.
عكس ٢ ← 4- i Leads V by 300°.

إعداد:-م.سجى البزايعه

∴ Note :-

لا نضع إشارة سالبة للزوايا نكتفي بكلمة (Lag) .

Q :- if $V_{max} = V_m = 20V$, $T = 1ms$, at $t = 0$
$V(0) = 10\,V$.

1) $V(t) = V_m \sin(wt + \theta)$

2) $F = \frac{1}{T} = \frac{1}{1\times10^{-3}} = 1000\ (HZ)$.

3) $W = 2\pi F = 2\pi(1000) = 2000\pi\ (rad/sec.)$.

4) To Find (θ) :-

$V(0) = 20 \sin(2000\pi \times 0 + \theta)$

$10 = 20 \sin(\theta)$

$\sin(\theta) = \frac{1}{2}$

$\theta = \frac{\pi}{6}\ (rad/sec.) = 30^\circ$.

so :- $V(t) = 20 \sin(2000\pi t + \frac{\pi}{6})$ volt .

- Complex Forcing Functions :-

1- polar Form :- $Ae^{j\theta} = A\angle\theta$

2- rectangular Form :- $X + jy$

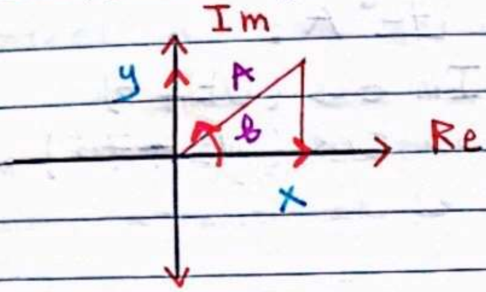
⟹ To convert from (rectangular Form) to (polar Form) use :-

$A = \sqrt{X^2 + y^2}$ ⟹ Amplitude

$\theta = \tan^{-1}\left(\frac{y}{X}\right)$ ⟹ phase

⟹ To convert from (polar form) to (rectangular form) use :-

مركبة افقية ← $x = A\cos\theta$ ⟹ Real part (Re)
مركبة عامودية ← $y = A\sin\theta$ ⟹ Imaginary part (Im)



∴ Note :-
ولكننا لسنا بحاجة لاستخدام هذه القوانين ، فبإمكاننا التحويل بين (polar Form) و (rectangular Form) باستخدام الآلة الحاسبة .

Q :- By using the calculator :-

a) $I = -3 + j4$, convert to phasor form :-
$I = 5\angle{-53.13^\circ} = 5\angle{126.86^\circ}$ A .

b) $I = 4\angle{30^\circ}$, convert to rectangular form :-
$I = 2\sqrt{3} + j2$ A .

Q :- Find the time domain form for :-

a) $I = 5 + j10$
- convert to (polar form) :-
$I = 11.18\angle{63.43^\circ}$ A .
- convert to (time domain) :-
$I(t) = I_m \cos(wt + \theta)$
$I(t) = 11.18 \cos(wt + 63.43^\circ)$ A .

∴ Note :-

• بـ (circuit "2") رايحين نتعامل مع cos وليس sin .

b) $I = j5 \times 7e^{-j20}$

$I = 5\angle 90^\circ \times 7\angle -20^\circ$

$\underline{I} = 35\angle 70^\circ$ A .

$I(t) = I_m \cos(wt + \theta)$

$I(t) = 35 \cos(wt + 70^\circ)$.

∴ Note :-

— (polar form / rectangular form) → frequency domain .

— Instantaneous form → time domain .

Q :- calculate the phase angle between :-

$X(t) = 13 \cos(2t) + 5 \sin(2t)$

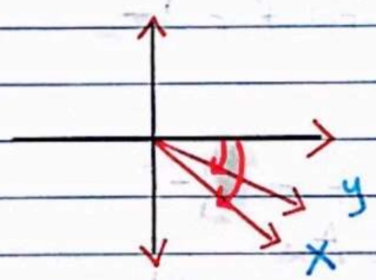
$y(t) = 15 \cos(2t - 11.8^\circ)$

→ $X(t) = 13 \cos(2t) + 5 \cos(2t - 90^\circ)$.

→ $X(t) = 13\angle 0^\circ + 5\angle -90^\circ$

$X(t) = 13.92\angle -21.03^\circ$.

→ $X(t) = 13.92 \cos(wt - 21.03^\circ)$.



— $\theta_1 = 21.03^\circ - 11.8^\circ$
$= 9.23^\circ$.

— $\theta_2 = 360^\circ - 9.23^\circ$
$= 350.77^\circ$.

so :- 1- y Leads X by 9.23° .

2- X Lags y by 9.23° .

3- y Lags X by 350.77°.

4- X Leads y by 350.77°.

Q:- given $i_1(t) = 4\cos(wt+30°)$ and $i_2(t) = 5\sin(wt-20°)$, Find their sum:-

- convert to polar Form:-

$i_1(t) = 4\angle 30°$.

$i_2(t) = 5\cos(wt-20°-90°)$

$\rightarrow i_2(t) = 5\cos(wt-110°)$.

$\rightarrow i_2(t) = 5\angle -110°$.

- Find the sum:-

$I = I_1 + I_2$

$= 4\angle 30° + 5\angle -110°$

- By using calculator:-

$I = 3.218\angle -56.9°\ A$.

- convert to time domain:-

$i(t) = 3.218\cos(wt-56.9°)\ A$.

∴ Note:-

لازم اتأكد من الزاوية في الآلة الحاسبة إذا بالـ (Rad) او بالـ (degree).

- Electrical elements in (Ac circuits):-

1- Z :- Impedence , ohm (Ω).

$$Z = \frac{\text{phasor voltage}}{\text{phasor current}} = \frac{V\angle\theta}{I\angle\theta} \quad \ldots\ \boxed{1}$$

$\rightarrow \theta_Z = \theta_V - \theta_I$

2- R :- Resistor و ohm (Ω) .

$$Z_R = \frac{V}{I} \quad .... \boxed{2}$$

3- L :- Inductor و ohm (Ω) .

$$Z_L = jwL \quad .... \boxed{3}$$

4- C :- Capacitor و ohm (Ω) .

$$Z_C = \frac{1}{jwC} = \frac{-j}{wC} \quad .... \boxed{4}$$

5- Y :- Admittance و semins (Ω^{-1})/(S) .

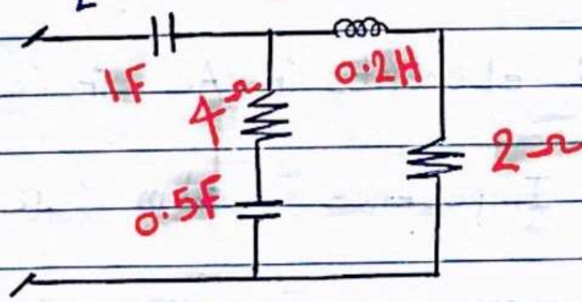
$$Y = \frac{1}{Z} \quad .... \boxed{5}$$

6- X :- Reactance و ohm (Ω) .

$$X_L = wL \quad .... \boxed{6}$$

$$X_C = \frac{-1}{wC} \quad .... \boxed{7}$$

Q :- Find Z_{eq} و if [$w = 50$ rad/s] :-



$$Z_{R_1} = 2\ \Omega$$

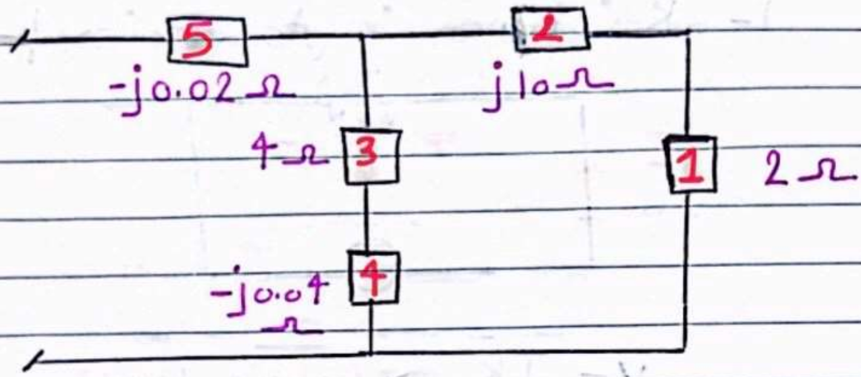
$Z_L = jwL = j(50 \times 0.2) = j10\ \Omega.$

$Z_{C_1} = \frac{1}{jwc} = \frac{-j}{(50 \times 0.5)} = -j0.04\ \Omega.$

$Z_{R_2} = 4\ \Omega.$

$Z_{C_2} = \frac{1}{jwc} = \frac{-j}{(50 \times 1)} = -j\,0.02\ \Omega.$

so :-



→ [(1, 2) series] parallel [(3, 4) series] seriese(5).

$Z_{eq} = \underbrace{\left[(j10 + 2) // (4 - j0.04)\right]} + -j0.02$

$* \ \frac{(j10+2) \times (4 - j0.04)}{(j10+2) + (4 - j0.04)} = 3.38 + j1.26.$

so :- $Z_{eq} = 3.38 + j1.26 - j0.02$

$Z_{eq} = 3.38 + j1.24 = 3.6 \angle 20^\circ\ \Omega.$

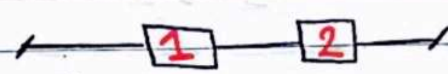
∴ Note :-

لإيجاد محصلة الـ (impedence) الموصولة على التوازي (parallel).

[حاصل الضرب/حاصل الجمع]

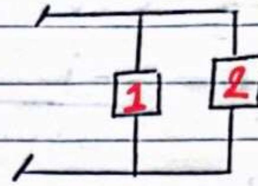
∴ Remember :-

1- series :-



$Z_{eq} = Z_1 + Z_2$

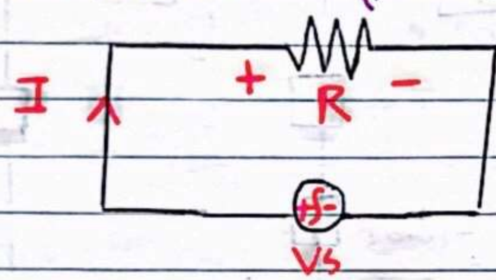
2- parallel :-



$$Z_{eq} = \frac{Z_1 \times Z_2}{Z_1 + Z_2}$$

- phasor relationships for circuit elements :-

1- Resistance in (Ac circuits) :-



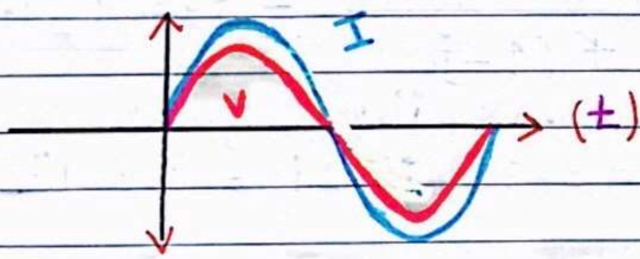
$V = IR \rightarrow$ (ohm's Law)

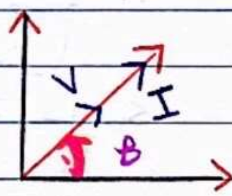
$v(t) = I(t) \cdot R \rightarrow$ (instantaneous form)

$V_m \angle \theta_v = I_m \angle \theta_I \cdot R \rightarrow$ (phasor form)

so :- - $V_m = I_m \cdot R$

- $\theta_v = \theta_I \rightarrow$ (V, I) are (in phase).



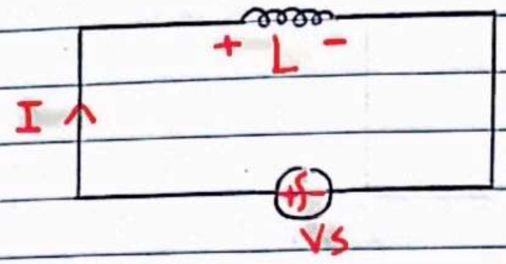


so :- $Z_R = \frac{V \angle \theta_v}{I \angle \theta_I} = \frac{V}{I} \angle \theta_v - \theta_I = \frac{V}{I}$

و $\theta_Z = \theta_v - \theta_I = \text{Zero}$ و In phase.

إعداد:-م.سجى البزايعه

2- Inductor in (AC circuits) :-



$V = jwL \cdot I$

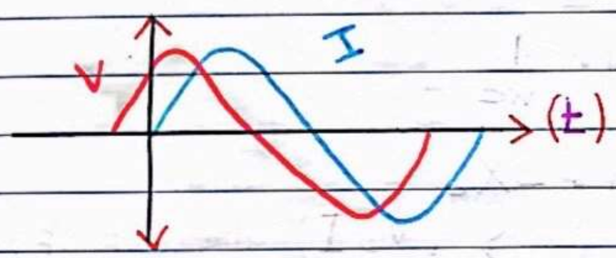
$v(t) = jwL \cdot I(t)$ → (Instantaneous form)

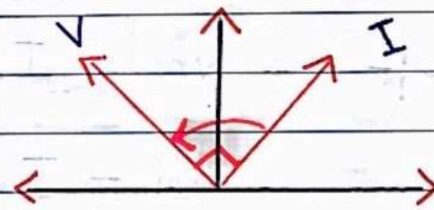
$v_m \angle \theta v = wL \angle 90° \cdot I_m \angle \theta I$ → (phasor form)

so:- - $v_m = I_m \cdot wL$

$v_m = I_m \cdot X_L$

- $\theta v \neq \theta I$ → (V, I) are (out of phase).





so:- $Z_R = \dfrac{V \angle \theta V}{I \angle \theta I} = \dfrac{V}{I} \angle \theta V - \theta I = \dfrac{V}{I} \angle 90°$

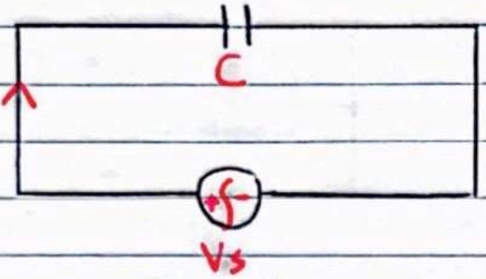
, $\theta Z = \theta V - \theta I = 90° = \dfrac{\pi}{2}$ rad ,

out of phase.

so:- V Leads I by 90°.

I Lags V by 90°.

3- Capacitor in (AC circuits) :-



$$V = I \cdot \frac{1}{j\omega c}$$

$$v(t) = \frac{1}{j\omega c} \cdot I(t) \longrightarrow \text{(Instantaneous form)}$$

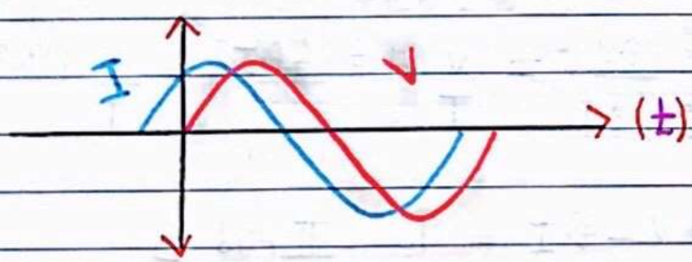
$$v(t) = \frac{-j}{\omega c} \cdot I(t)$$

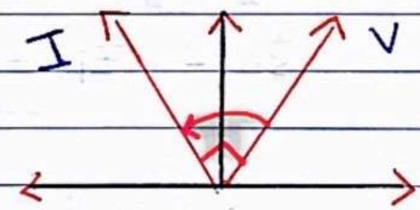
$$v_m \angle \theta_v = \frac{1}{\omega c} \angle -90^\circ \cdot I_m \angle \theta_I \rightarrow \text{(phasor form)}$$

so :- – $v_m = I_m \cdot \frac{1}{\omega c}$

$v_m = I_m \cdot -X_c$

– $\theta_v \neq \theta_I \longrightarrow$ (V, I) are (out of phase).





so :- $Z_R = \frac{V \angle \theta_v}{I \angle \theta_I} = \frac{V}{I} \angle \theta_v - \theta_I = \frac{V}{I} \angle -90^\circ$

و $\theta_z = \theta_v - \theta_I = -90^\circ = \frac{-\pi}{2}$ rad و

out of phase.

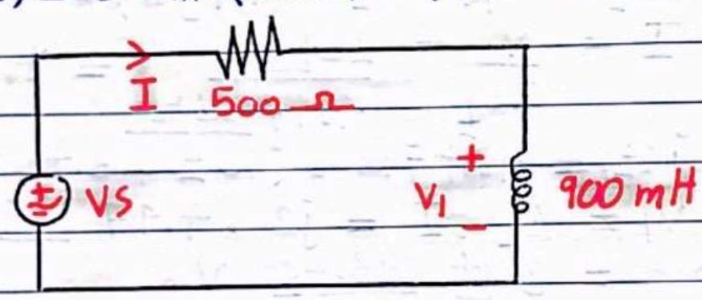
so :- V Lags I by 90° .

I Leads V by 90° .

∴ Note :-

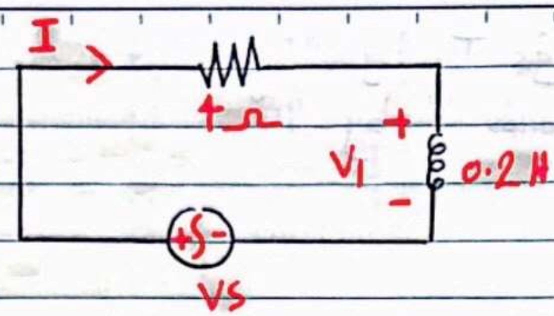
- $j = 1\angle 90^\circ$
- $-j = 1\angle -90^\circ$

Q :- Determine the following, [$v(t)$ / $v_1(t)$], If $i(t) = 8\sin(10t + 30^\circ)$ A .



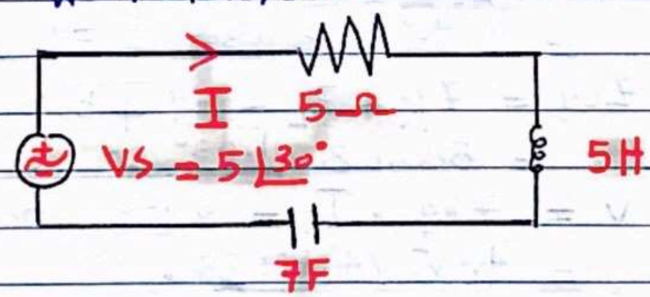
- $I = 8\angle 30^\circ$.
- $Z_R = 500\ \Omega$.
- $Z_L = j\omega L = j(10 \times 900 \times 10^{-3}) = j9\ \Omega$.
- $V_1 = Z_L \cdot I = j9 \times 8\angle 30^\circ =$
  $= 9\angle 90^\circ \cdot 8\angle 30^\circ = 72\angle 120^\circ$ V .
- $Z_{eq} = Z_R + Z_L = j9 + 500 =$
  $= 500.08\angle 1.03^\circ\ \Omega$.
- $V = Z_{eq} \cdot I = 8\angle 30 \cdot 500.08\angle 1.03^\circ$
  $= 4000.64\angle 31.03^\circ$.
- $V_1(t) = 72\sin(10t + 120^\circ)$ V .
- $V(t) = 4000.64\sin(10t + 31.03^\circ)$ V .

Q :- Determine the following, [$v_1(t)$ / $i(t)$ / X_L], If $v(t) = 20\cos(10t + 30^\circ)$ V .



- $V = 20 \angle 30^\circ$ V.
- $Z_R = 4\ \Omega$.
- $Z_L = jWL = j(10 \times 0.2) = j2\ \Omega$.
- $Z_{eq} = Z_R + Z_L = (4 + j2) = 4.47 \angle 26.56^\circ\ \Omega$.
- $I = \dfrac{V}{Z_{eq}} = \dfrac{20 \angle 30^\circ}{4.47 \angle 26.56^\circ} = 4.47 \angle 3.43^\circ$ A.
- $i(t) = 4.47 \cos(10t + 3.43^\circ)$ A.
- $V_1 = Z_L \cdot I = j2 \cdot 4.47 \angle 3.43^\circ =$
  $= 8.94 \angle 93.43^\circ$ V.
- $V_1(t) = 8.94 \cos(10t + 93.43^\circ)$ V.
- $X_L = WL = 10 \times 0.2 = 2\ \Omega$.

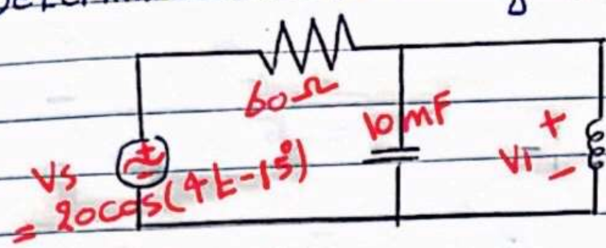
Q) - Determine the Following, [Z_{eq} / I],
IF $W = 10$ rad/s.



- $Z_R = 5\ \Omega$.
- $Z_L = jWL = j(5 \times 10) = j50\ \Omega$.
- $Z_C = \dfrac{1}{jWC} = \dfrac{-j}{(10 \times 7)} = \dfrac{-j}{70} = -j0.0143\ \Omega$.
- $Z_{eq} = Z_R + Z_L + Z_C$
  $= 5 + j50 - j0.0143$
  $= 5.021 \angle 84.28^\circ$.

$- I = \frac{V}{Z_{eq}} = \frac{5\angle 30^\circ}{5.021\angle 84.28^\circ} = 0.0995\angle -54.28^\circ \text{ A}.$

① :- Determine the Following , $[v_1(t) / X_L / X_C]$.



- $V = 20\angle -15^\circ$ V.
- $Z_R = 60\,\Omega$.
- $Z_L = j\omega L = j(4\times 5) = j20\,\Omega$.
- $Z_C = \frac{1}{j\omega C} = \frac{-j}{(4\times 10\times 10^{-3})} = -j25\,\Omega$.
- $X_L = \omega L = (4\times 5) = 20\,\Omega$.
- $X_C = \frac{-1}{\omega C} = \frac{-1}{(4\times 10\times 10^{-3})} = -25\,\Omega$.

- $V_1 = \frac{V_S \times (Z_C // Z_L)}{(Z_C // Z_L) + Z_R}$ (voltage division)

- $(Z_C // Z_L) = \frac{j20 \times -j25}{j20 + -j25} = j100\,\Omega$.

- $V_1 = \frac{20\angle -15^\circ \times j100}{j100 + 60} = 17.15\angle 15.96^\circ$ V.

- $v_1(t) = 17.15\cos(4t + 15.96^\circ)$ V.

∴ Note :-

$Z = R + jX \rightarrow X_L = \omega L$, $X_C = \frac{-1}{\omega C}$

so :- $Y = \frac{1}{Z} = \frac{1}{(R + jX)} = \frac{1}{R} \mp j\frac{1}{X}$

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$= G \mp jB$

so :- $y = (G \mp jB)\ \Omega^{-1}$.

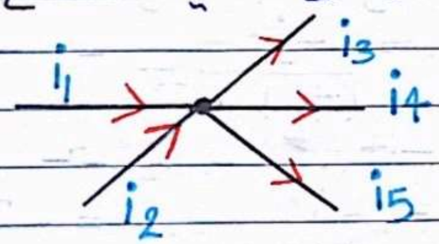
Revision :-

- Nodal Analysis :-

* Kirchoff's current Law (KCL) :-

ينص هذا القانون على :-

إنّ [مجموع التيارات الداخلة إلى نقطة معينة = مجموع التيارات الخارجة من نقطة معينة]



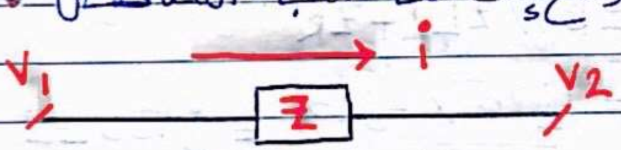
$i_1 + i_2 = i_3 + i_4 + i_5$

$\sum I_{in} = \sum I_{out}$

$\sum I = Zero$

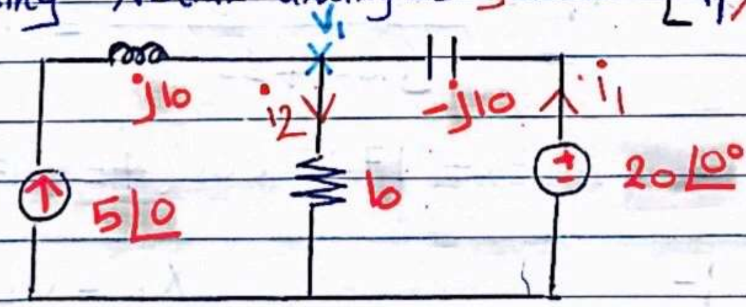
∴ Note :-

التيار يعبر من نقطة الجهد المرتفع إلى نقطة الجهد المنخفض.



$i = \frac{V_1 - V_2}{Z}$

Q :- By using Nodal analysis , find $[V_1 / i_1 / i_2]$.



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- $\sum I_{in} = \sum I_{out}$

$$i_1 + 5\angle 0^\circ = i_2$$

$$\left(\frac{20\angle 0^\circ - V_1}{-j10}\right) + 5\angle 0^\circ = \left(\frac{V_1 - 0}{10}\right)$$

$$\frac{20\angle 0^\circ}{-j10} - \frac{V_1}{-j10} + 5\angle 0^\circ = \frac{V_1}{10}$$

$$\frac{20}{-j10} + 5 = \frac{V_1}{10} + \frac{V_1}{-j10}$$

$$\frac{20}{-j10} + 5 = V_1\left[\frac{1}{10} + \frac{1}{-j10}\right]$$

$$(j2 + 5) = V_1\,(0.1 + j0.1)$$

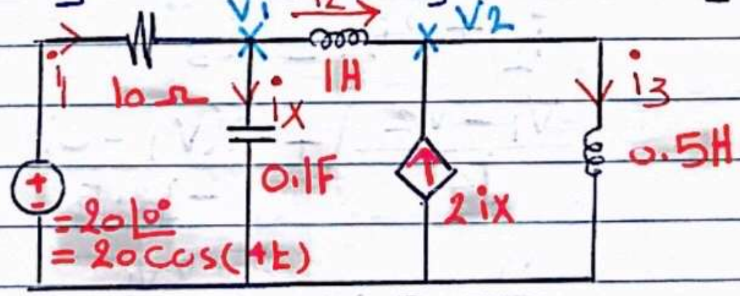
$$V_1 = (35 - j15) = 38.07\angle -23.1^\circ \text{ V}.$$

- $i_1 = \dfrac{20\angle 0^\circ - V_1}{-j10} = \dfrac{20\angle 0^\circ - 38.07\angle -23.1^\circ}{-j10}$

$$i_1 = 2.118\angle -134.84^\circ \text{ A}.$$

- $i_2 = \dfrac{V_1 - 0}{10} = \dfrac{38.07\angle -23.1^\circ}{10} = 3.807\angle -23.1^\circ \text{ A}.$

Q 1- By using Nodal analysis, Find $[V_1 / V_2]$.



- $Z_{L1} = j\omega L = j(4 \times 1) = j4\ \Omega$.
- $Z_C = \dfrac{1}{j\omega C} = \dfrac{-j}{(4 \times 0.1)} = -j2.5\ \Omega$.

- $Z_{L2} = j\omega L_2 = j(4 \times 0.5) = j2\ \Omega$.

- $\sum I_{in} = \sum I_{out}$, at node 1 :-

$$i_1 = i_x + i_2$$

$$\left(\frac{20\angle 0^\circ - V_1}{10}\right) = \frac{V_1 - 0}{-j2.5} + \frac{V_1 - V_2}{j4}$$

$$\frac{20}{10} - \frac{V_1}{10} = \frac{V_1}{-j2.5} + \frac{V_1}{j4} - \frac{V_2}{j4}$$

$$2 = \frac{V_1}{-j2.5} + \frac{V_1}{j4} + \frac{V_1}{10} - \frac{V_2}{j4}$$

$$2 = V_1\left[\frac{1}{-j2.5} + \frac{1}{j4} + \frac{1}{10}\right] - \frac{V_2}{j4}$$

$$2 = V_1\left[\frac{j}{2.5} - \frac{j}{4} + 0.1\right] + \frac{j V_2}{4}$$

$$\left(2 = V_1\left[0.1 + j0.4 - j0.25\right] + j0.25 V_2\right) \times 10$$

$$j2.5V_2 + \left[1 + j1.5\right] V_1 = 20 \quad \dots (1)$$

- $\sum I_{in} = \sum I_{out}$, at node 2 :-

$$i_2 + 2i_x = i_3$$

$$\left(\frac{V_1 - V_2}{j4}\right) + \frac{2(V_1 - 0)}{-j2.5} = \frac{V_2}{j2}$$

$$\frac{V_1}{j4} - \frac{V_2}{j4} + \frac{2V_1}{-j2.5} = \frac{V_2}{j2}$$

$$\left[-j0.25 + j0.8\right] V_1 + \left[j0.25 + j0.5\right] V_2 = 0$$

$$(j0.55\, V_1 + j0.75\, V_2 = 0) \times 20$$

$$11 V_1 + 15 V_2 = 0 \quad \ldots (2)$$

- By using (Carmer's rule) :-

$$(1 + j1.5)\, V_1 + j2.5\, V_2 = 20$$
$$11\, V_1 + 15 V_2 = 0$$

$$\begin{bmatrix} 1+j1.5 & j2.5 \\ 11 & 15 \end{bmatrix} \begin{bmatrix} V_1 \\ V_2 \end{bmatrix} = \begin{bmatrix} 20 \\ 0 \end{bmatrix}$$

$$\Delta = 15 \times (1+j1.5) - 11 \times j2.5$$
$$= 15 + j22.5 - j27.5$$
$$= 15 + -j5 = 15.8 \angle -18.43^\circ$$

$$\Delta V_1 = \begin{bmatrix} 20 & j2.5 \\ 0 & 15 \end{bmatrix}$$

$$= 20 \times 15 - 0 \times j2.5$$
$$= 300$$

$$\Delta V_2 = \begin{bmatrix} 1+j1.5 & 20 \\ 11 & 0 \end{bmatrix}$$

$$= 1 + j1.5 \times 0 - 20 \times 11$$
$$= -220$$

$$V_1 = \frac{\Delta V_1}{\Delta} = \frac{300}{15.8 \angle -18.43^\circ} = 18.98 \angle 18.43^\circ \, V.$$

$$V_2 = \frac{\Delta V_2}{\Delta} = \frac{-220}{15.8 \angle -18.43^\circ} = -13.9 \angle 18.43^\circ \, V. = 13.9 \angle -161.56^\circ \, V.$$

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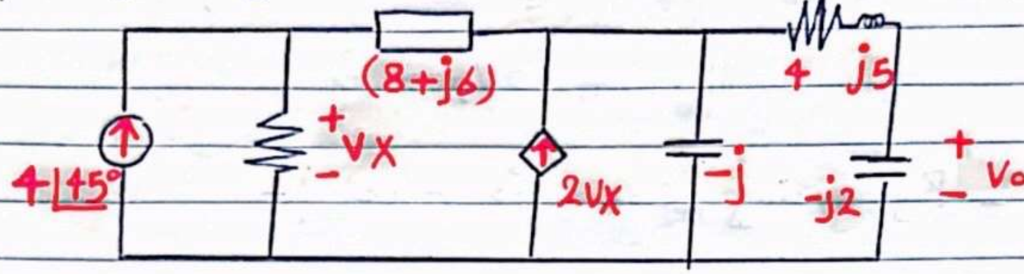
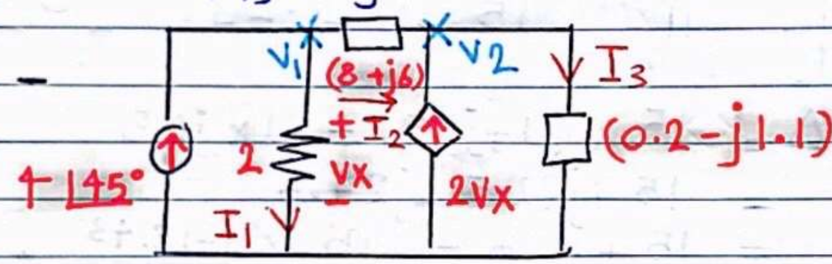
Q :- By using Nodal analysis , determine V_o :-



- $= (4 + j5 - j2) \,//\, -j$

$$= \frac{(4+j3) \times -j}{4+j3-j} = [0.2 - j1.1]\ \Omega .$$



- KCL at node 1 :-

$$4\angle 45^\circ = I_1 + I_2$$

$$4\angle 45^\circ = \frac{V_1}{2} + \left(\frac{V_1 - V_2}{8+j6}\right)$$

$$4\angle 45^\circ = \frac{V_1}{2} + \frac{V_1}{8+j6} - \frac{V_2}{8+j6}$$

$$4\angle 45^\circ = V_1\left[\frac{1}{2} + \frac{1}{8+j6}\right] - \frac{V_2}{8+j6}$$

$$4\angle 45^\circ = [0.5 + 0.08 + -j0.06]\,V_1 - [0.08 - j0.06]\,V_2$$

$$50\times\left(4\angle 45^\circ = [0.58 - j0.06]V_1 - [0.08 - j0.06]V_2\right)$$

$$[29 - j3]V_1 + [-4 + j3]V_2 = 200\angle 45^\circ \quad \ldots (1)$$

- KCL at node 2 :-

$$I_2 + 2VX = I_3$$

$$\left(\frac{V_1 - V_2}{(8+j6)}\right) + 2VX = \frac{V_2 - 0}{0.2 - j1.1}$$

$$\left(\frac{V_1 - V_2}{8+j6}\right) + 2V_1 = \frac{V_2}{0.2 - j1.1}$$

$$\frac{V_1}{8+j6} - \frac{V_2}{8+j6} + 2V_1 - \frac{V_2}{0.2 - j1.1} = 0$$

$$V_1[2 + 0.08 - j0.06] - V_2[0.08 - j0.06 \; 0.16 + j0.88] = 0$$

$$50\times\left([2.08 - j0.06]V_1 - [0.24 - j0.82]V_2 = 0\right)$$

$$[104 - j3]V_1 + [-12 - j4]V_2 = 0 \quad \ldots (2)$$

- By (Carmer's ruLe) :-

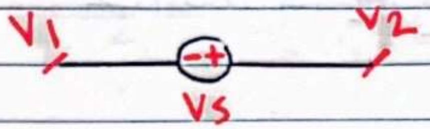
$$V_1 = 5.77\angle 31.16^\circ \text{ V}$$

$$V_2 = 14.074\angle -44.16^\circ \text{ V}$$

Voltage division ← $V_o = \dfrac{V_2 \times -j2}{4 + j5 - j2} = 5.629\angle -71.02^\circ \text{ V}$

- super node :-

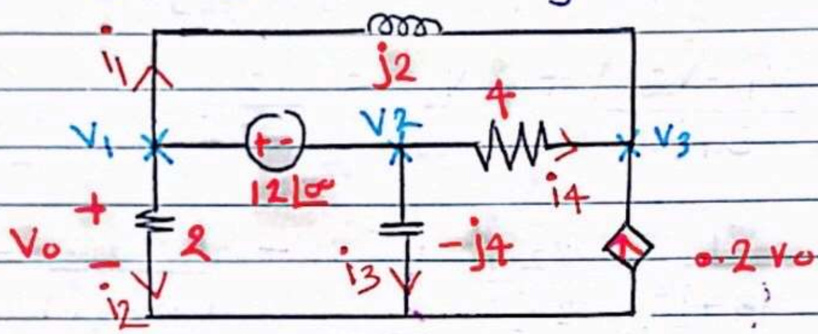
في هذه الحالة يكون هنالك مصدر جهد بين (2 nodes) كما يلي :-



$V_s = V_2 - V_1$

جهد مرتفع   جهد منخفض

Q :- By using Nodal analysis , Find Vo :-



- super node :- $V_1 - V_2 = 12\angle 0°$ ... (1)

- KCL at node 1 :-

$$i_1 = i_2$$

$$\left(\frac{V_1 - V_3}{j2}\right) = \frac{V_1}{2}$$

$$\frac{V_1}{j2} - \frac{V_3}{j2} - \frac{V_1}{2} = 0$$

$$V_1\left[-0.5 - j0.5\right] - j0.5 = 0 \quad \text{... (2)}$$

- KCL at node 2 :-

$$i_3 + i_4 = 0$$

$$\frac{V_2 - 0}{-j4} + \frac{V_2 - V_3}{4} = 0$$

$j0.25V_2 + 0.25V_2 - 0.25V_3 = 0$

$[0.25 + j0.25]V_2 - 0.25V_3 = 0 \quad \ldots (3)$

- KCL at node 3 :-

$i_4 + i_1 + 0.2V_0 = 0$

$\left(\frac{V_2 - V_3}{4}\right) + \left(\frac{V_1 - V_3}{j2}\right) + 0.2V_1 = 0$

$\frac{V_2}{4} - \frac{V_3}{4} + \frac{V_1}{j2} - \frac{V_3}{j2} + 0.2V_1 = 0$

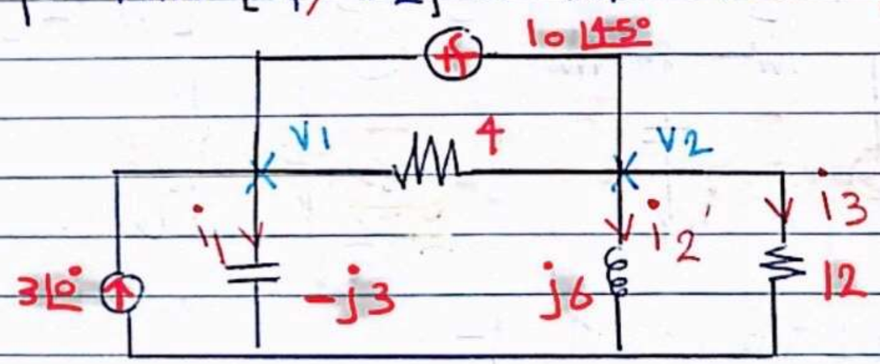
$[0.2 + j0.5]V_1 + 0.25V_2 - [0.25 + j0.5]V_3 = 0 \quad \ldots (4)$

- By (cramer's rule) :-

$V_1 = V_0 = 7.682 \angle 50.19^\circ \text{ V}$

$V_2 = 9.218 \angle 140.19^\circ \text{ V}$

(4) :- Find $[V_1 / V_2]$ in the circuit :-



- super node :- $V_1 - V_2 = 10\angle 45^\circ \quad \ldots (1)$

- KCL at node 1 and node 2 :-

$3\angle 0^\circ = i_1 + i_2 + i_3$

$3\angle 0^\circ = \frac{V_1}{-j3} + \frac{V_2}{j6} + \frac{V_2}{12}$

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$$3 = j0.33V_1 - j0.166V_2 + 0.083V_2$$

$$(3 = j0.33V_1 + [0.083 - j0.166]V_2) \times 12$$

$$j4V_1 + [1 - j2]V_2 = 36 \quad \dots (2)$$

- By (carmer's rule) :-

$$V_1 = 25.78 \angle -70.48^\circ \ V$$

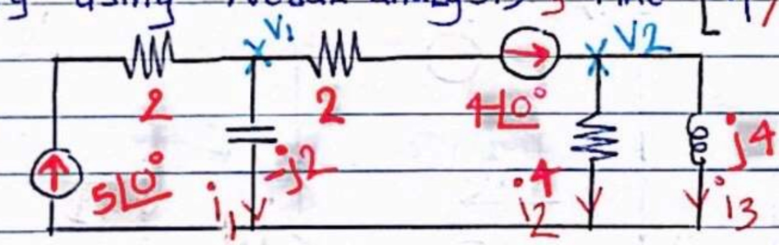
$$V_2 = 31.41 \angle -87.18^\circ \ V$$

∴ Note :-

في حال كان هنالك مصدر تيار كهربائي بين (2nodes) كمايلي :-

أي شيء عدا مصدر التيار الكهربائي لا يدخل في الحسابات .

(4) :- By using Nodal analysis, Find $[V_1/V_2]$:-



- KcL at node 1 :-

$$5\angle 0^\circ = i_1 + 4\angle 0^\circ$$

$$5\angle 0^\circ = \frac{V_1}{-j2} + 4\angle 0^\circ$$

$$1 = \frac{V_1}{-j2}$$

$$V_1 = -j2 \ V.$$

- KCL at node 2 :-

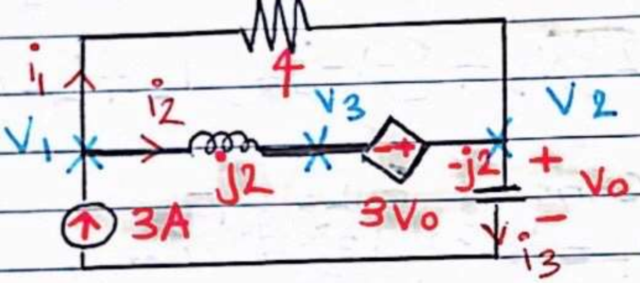
$$4\angle 0^\circ = i_2 + i_3$$

$$4\angle 0^\circ = \frac{V_2}{4} + \frac{V_2}{j4}$$

$$V_2 \left[\frac{1}{4} + \frac{1}{j4}\right] = 4$$

$$V_2 = [8 + j8]\ \Omega .$$

Q :- For the circuit in the Figure, Find $[V_1 / V_2]$ using Nodal analysis :-



- super node :- $V_2 - V_3 = 3V_o$, $V_o = V_2$

so :- $V_2 - V_3 = 3V_2$

$$-2V_2 - V_3 = 0 \quad \dots (1)$$

- KCL at node 1 :-

$$3 = i_1 + i_2$$

$$3 = \left[\frac{V_1 - V_2}{4}\right] + \left[\frac{V_1 - V_3}{j2}\right]$$

$$3 = \frac{V_1}{4} - \frac{V_2}{4} + \frac{V_1}{j2} - \frac{V_3}{j2}$$

$$\left(3 = \frac{-V_2}{4} - \frac{V_3}{j2} + V_1 \left[\frac{1}{4} + \frac{1}{j2}\right] \right) \times 4$$

$$[1 - j2]\, V_1 - V_2 + j2\, V_3 = 12 \quad \dots (2)$$

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- KCL at node 2 :-

$$i_1 + i_2 = i_3$$

$$\left[\frac{V_1 - V_2}{4}\right] + \left[\frac{V_1 - V_3}{j2}\right] = \frac{V_2}{-j2}$$

$$\frac{V_1}{4} - \frac{V_2}{4} + \frac{V_1}{j2} - \frac{V_3}{j2} - \frac{V_2}{-j2} = 0$$

$$\left(V_1\left[\frac{1}{4} + \frac{1}{j2}\right] + V_2\left[\frac{-1}{4} - \frac{1}{-j2}\right] - \frac{V_3}{j2} = 0 \right) \times 4$$

$$[1 - j2]V_1 + [-1 - j2]V_2 + j2V_3 = 0 \quad \dots (3)$$

- By (Carmer's rule) :-

$V_1 = 16.32 \angle 53.97^\circ$ V.

$V_2 = 6 \angle 90^\circ$ V.

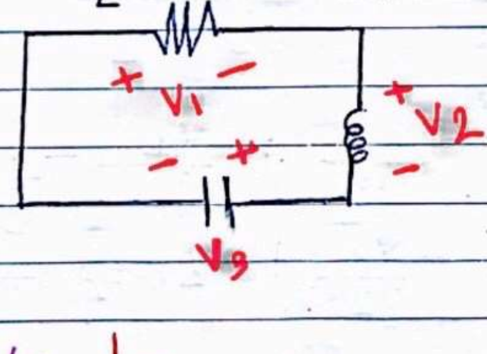
$V_3 = 12 \angle -90^\circ$ V.

- Mesh Analysis :-

* Kirchoff's voltage Law (KVL) :-

ينص هذا القانون على :-

إنّ [مجموع الجهود في حلقة واحدة = صفر]



$$V_1 + V_2 + V_3 = \text{Zero}$$

∴ Note :-

* الفرق بين الـ Mesh والـ Loop :-

- Mesh :- هو أصغر حلقة أو مسار مغلق في الدارة .

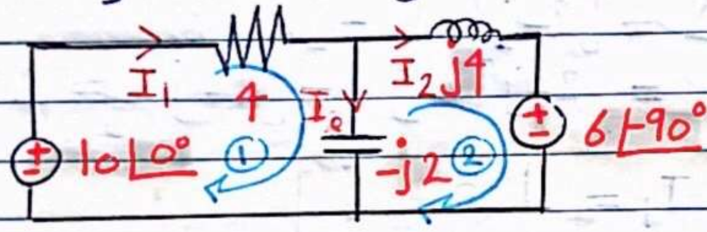
- Loop :- قد يحتوي على أكثر من Mesh وهو مسار مغلق في الدارة.

* - كل Mesh ← Loop .

- ليس كل Loop ← Mesh .

---

① :- By using Mesh analysis , Find I_o :-



- KVL at Loop 1 :-

$$-10\angle 0 + 4I_1 - j2\,[I_1 - I_2] = 0$$

$$4I_1 - j2I_1 + j2I_2 = 10$$

$$\left([4 - j2]I_1 + j2I_2 = 10\right) \div 2$$

$$[2 - j]I_1 + jI_2 = 5 \quad \dots ①$$

- KVL at Loop 2 :-

$$j4I_2 + 6\angle -90° + -j2\,[I_2 - I_1] = 0$$

$$j4I_2 - j2I_2 + j2I_1 = -6\angle -90°$$

$$\left(j2I_2 + j2I_1 = -6\angle -90°\right) \div 2$$

$$\left(\cancel{j}I_2 + \cancel{j}I_1 = \cancel{+j}3\right)$$

$$I_2 + I_1 = 3 \quad \dots ②$$

- By (carmer's rule) :-

- $[2-j]I_1 + jI_2 = 5$
  $I_1 + I_2 = 3$

- $\begin{bmatrix} 2-j & j \\ 1 & 1 \end{bmatrix} \begin{bmatrix} I_1 \\ I_2 \end{bmatrix} = \begin{bmatrix} 5 \\ 3 \end{bmatrix}$

- $\Delta = [2-j] \times 1 - j \times 1$
  $= 2-j - j = [2-j2] = 2.83 \angle -45^\circ$.

- $\Delta I_1 = \begin{bmatrix} 5 & j \\ 3 & 1 \end{bmatrix}$

  $= 5 - j3 = 5.83 \angle -30.96^\circ$.

- $\Delta I_2 = \begin{bmatrix} 2-j & 5 \\ 1 & 3 \end{bmatrix}$

  $= [2-j] \times 3 - 5 \times 1$
  $= 6 - j3 - 5 = [1-j3]$
  $= 3.16 \angle -71.57^\circ$

- $I_1 = \frac{\Delta I_1}{\Delta} = \frac{5.83 \angle -30.96^\circ}{2.83 \angle -45^\circ}$
  $= 2.06 \angle 14.04^\circ$ A.

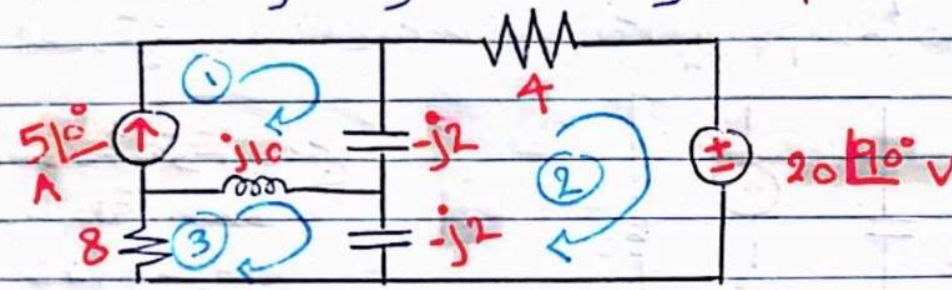
- $I_2 = \frac{\Delta I_2}{\Delta} = \frac{3.16 \angle -71.57^\circ}{2.83 \angle -45^\circ}$
  $= 1.11 \angle -26.56^\circ$ A.

- $I_o = I_1 - I_2$

$= 2.06 \angle 14.04^\circ - 1.11 \angle -26.56^\circ$

$= 1.42 \angle 44.73^\circ$ A.

(4) :- Find I_o by using mesh analysis :-



- $I_1 = 5\angle 0^\circ$ A.

- KVL at Loop 2 :-

$20\angle 90^\circ + 4I_2 + -j2(I_2 - I_3) + -j2(I_2 - I_1) = 0$

$[4 - j2 - j2]\, I_2 + j2 I_3 + j2 I_1 = -20\angle 90^\circ$

$[4 - j4]\, I_2 + j2 I_3 + j2 I_1 = -20\angle 90^\circ$

- [نعوّض I_1] :-

$[4 - j4]\, I_2 + j2 I_3 = -j30$ ... (1)

- KVL at Loop 3 :-

$8I_3 + j10\,[I_3 - I_1] + -j2\,[I_3 - I_2] = 0$

$[8 + j10 - j2]\, I_3 + -j10 I_1 + j2 I_2 = 0$

$[8 + j8]\, I_3 - j10 I_1 + j2 I_2 = 0$

- [نعوّض I_1] :-

$j2 I_2 + [8 + j8]\, I_3 = j50$ ... (2)

- By (Carmer's rule) :-

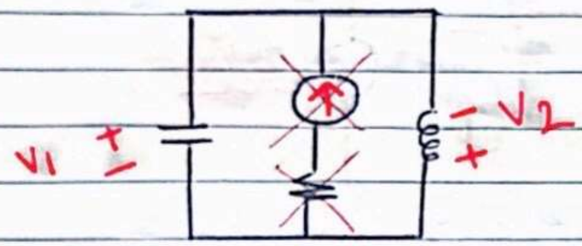
$I_2 = -6.12 \angle 144.78^\circ$ A .

so :- $I_o = -I_2$

$I_o = +6.12 \angle 144.78^\circ$.

- super mesh :-

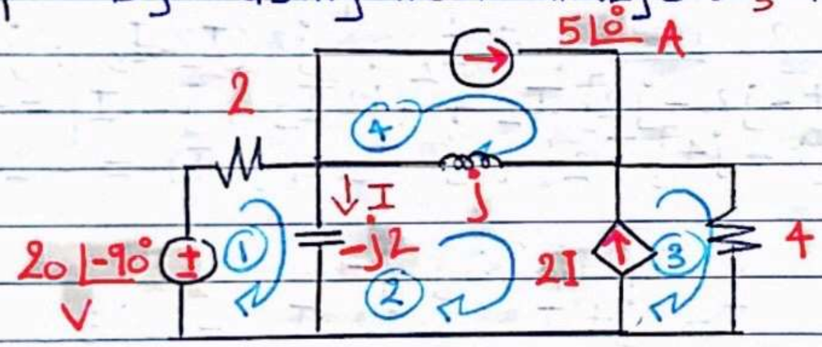
:- في هذه الحالة يكون هنالك مصدر كهربائي بين (2Loops) كما يلي



في هذه الحالة نقوم بدمج 2 Loops بمعادلة واحدة ، ولا يدخل هذا التيار في المعادلة وما معه من عناصر اخرى .

$-V_1 + -V_2 = \text{Zero}$

Q :- By using mesh analysis , Find I :-



- KVL For Loop 1 :-

$-20 \angle -90^\circ + 2I_1 + -j2\,[I_1 - I_2] = 0$

$[2 - j2]\,I_1 + j2\,I_2 = -j20$ ... ①

- $2I = I_3 - I_2$

- KVL For supermesh :-

$-j2\,[I_2 - I_1] + j\,[I_2 - I_4] + 4I_3 = 0$

$j2I_1 + [j - j2]\,I_2 + 4I_3 + -jI_4 = 0$

$j2I_1 + -jI_2 + 4I_3 + -jI_4 = 0$ ... ②

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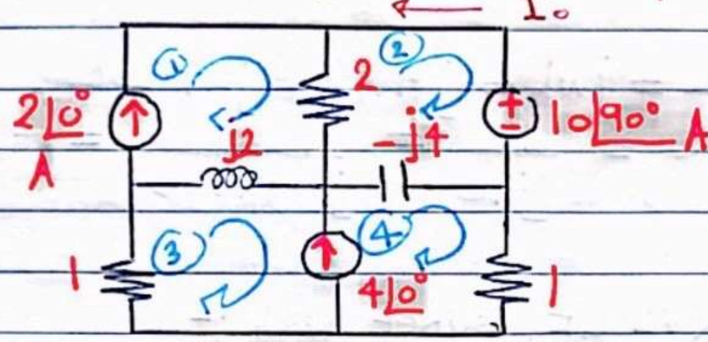
- $I_4 = 5\angle 0^\circ$ A.

- $I = I_1 - I_2 = 7.9\angle 43.4^\circ$ A.

Q :- By using mesh analysis, Find I_o :-



- $I_1 = 2\angle 0^\circ$ A.

- KVL at super mesh :-

$I_3 + j2[I_3 - I_1] + -j4[I_4 - I_2] + I_4 = 0$

$-j2I_1 + j4I_2 + [1+j2]I_3 + [1-j4]I_4 = 0$ ... (1)

- KVL at Loop 2 :-

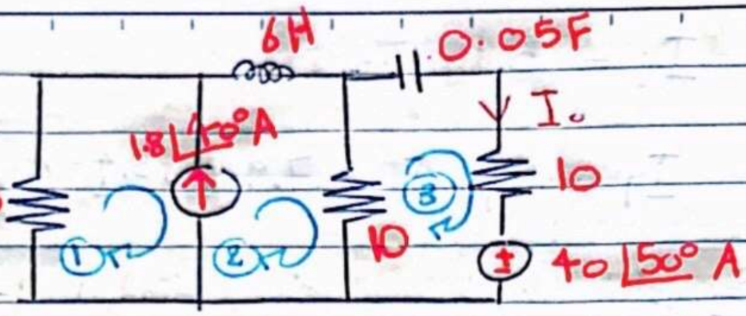
$2[I_2 - I_1] + 10\angle 90^\circ + -j4[I_2 - I_4] = 0$

$-2I_1 + [2-j4]I_2 + j4I_4 = 0$ ... (2)

- $I_4 - I_3 = 4\angle 0^\circ$ ... (3)

- $I_o = -I_2 = 3.25\angle 177.3^\circ$ A.

Q :- Determine I_o in the circuit of the figure, using mesh analysis, Assume $[W = 4\ rad/sec]$:-



– $X_L = j\omega L = j4 \times 6 = j24 \ \Omega$.

– $X_c = \frac{1}{j\omega c} = \frac{1}{j \times 4 \times 0.05} = -j5 \ \Omega$.

– KVL at super mesh :-

$10 I_1 + j24 I_2 + 10[I_2 - I_3] = 0$

$10 I_1 + [10 + j24] I_2 - 10 I_3 = 0 \ldots (1)$

– KVL at mesh 3 :-

$10[I_3 - I_2] + -j5 I_3 + 10 I_3 + 40 \angle 50^\circ = 0$

$-10 I_2 + 20 - j5 \ I_3 = 40 \angle -130^\circ \ldots (2)$

– $I_2 - I_1 = 1.8 \angle 40^\circ$ A

– By (Carmer's rule) :-

$I_1 = 2.04 \angle -133.26^\circ$ A.

$I_2 = 0.287 \angle -64.14^\circ$ A.

$I_3 = 2.066 \angle -114.27^\circ$ A.

so :- $I_o = I_3 = 2.066 \angle -114.27^\circ$ A.

Q :- By using mesh analysis, Find [I_o / I_1 / I_2 / I_3] :-

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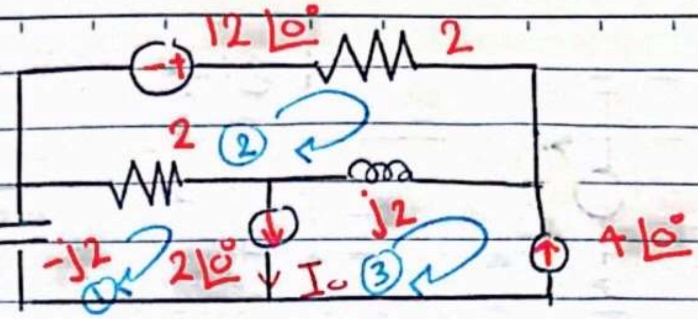

- $I_o = 2\angle 0°\ A$.

- $I_1 - I_3 = I_o$

$I_1 - I_3 = 2\angle 0°\ A$.

- $I_3 = -4\angle 0°\ A$.

so :- $I_1 = 2\angle 0° + -4\angle 0°$

$I_1 = -2\angle 0°\ A$.

- KVL at Loop 2 :-

$-12 + 2I_2 + j[I_2 - I_3] + 2[I_2 - I_1] = 0$

$-2I_1 + [4+j]I_2 + -jI_3 = 12$

$I_2 = [1.64 - j1.4]\ A$.

$[I_1 / I_3]$ بعد تعويض

- Super position theorem :-

- في هذه الحالة يكون هنالك اكثر من [independent source] بترددات مختلفة ، لذلك نقوم في كل مرة بحذف مصدر والإبقاء على المصدر الآخر ومن ثم اختيار طريقة الحل المناسبة.

- لا يتم حذف [dependent sources] ، لأن هذه العناصر تعتمد على مصادر أخرى.

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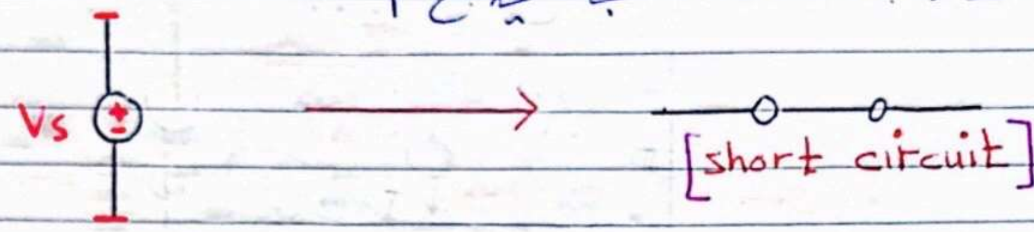
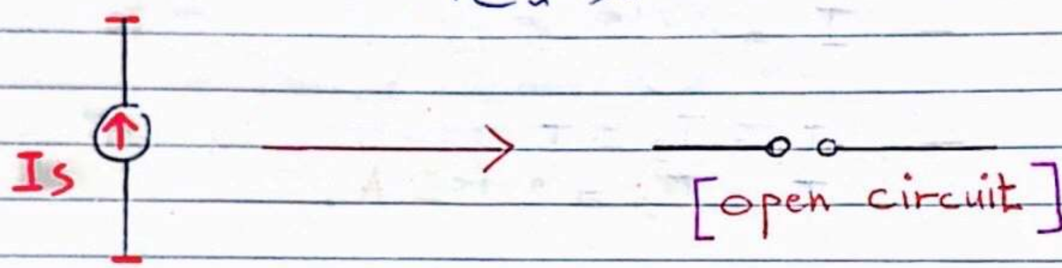
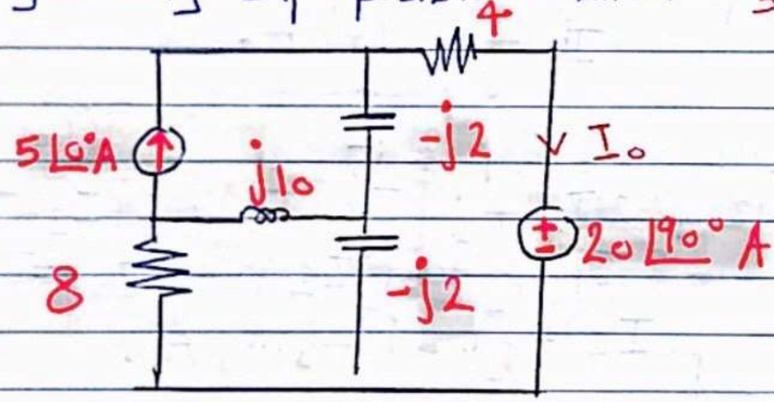
- عند حذف مصدر الجهد يصبح :-



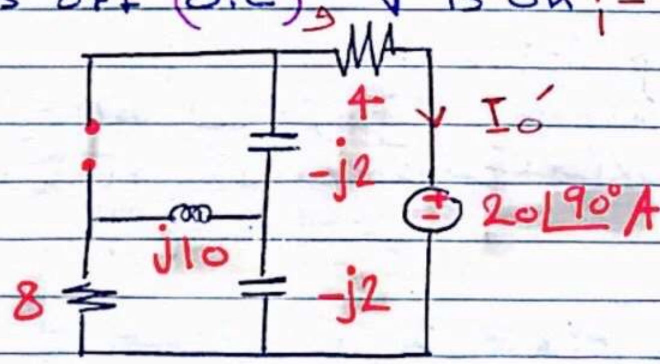
- عند حذف مصدر التيار يصبح :-



Q :- By using superposition theorem, Find I_o :-



- I is off (o.c), V is on :-

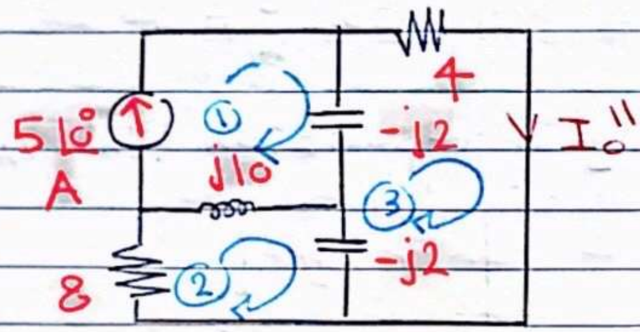


$$- \ Z_{eq} = \left[(8 + j10) \parallel -j2\right] + 4 - j2$$

$Z_{eq} = 6.01 \angle -45^\circ \ \Omega$.

- $I_o' = \dfrac{V}{Z_{eq}} = \dfrac{20 \angle 90^\circ}{6.01 \angle -45^\circ} = 3.32 \angle -45^\circ$ A.

- V is off (s.c) , I is on :-



- $I_1 = 5 \angle 0^\circ$.

- KVL at mesh 2 :-

$$-j2[I_2 - I_3] + j10[I_2 - I_1] + 8I_2 = 0$$
$$-j10 I_1 + [-j2 + j10 + 8] I_2 + j2 I_3 = 0$$

- [I_1 نعوض] :-

$$[8 + j8] I_2 + j2 I_3 = j50 \quad \ldots (1)$$

- KVL at mesh 3 :-

$$4 I_3 + -j2[I_3 - I_2] + -j2[I_3 - I_1] = 0$$
$$j2 I_1 + j2 I_2 + [4 - j2 - j2] I_3 = 0$$

- [I_1 نعوض] :-

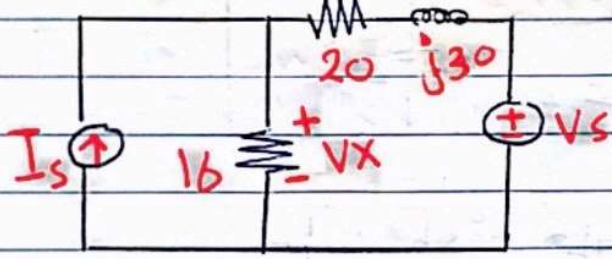
$$[4 - j4] I_3 + j2 I_2 = -j10 \quad \ldots (2)$$

- By (carmer's rule) :-

$I_2 = 3.95 \angle 48.01^\circ$ A .
$I_3 = 2.896 \angle -23.96^\circ$ A .

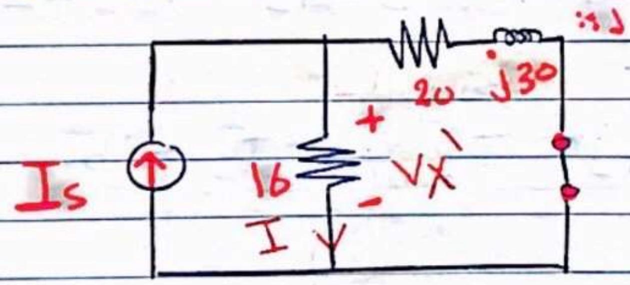
- $I_o = I_o' + I_o''$
$I_o' = 3.32 \angle -45^\circ$ A .
$I_o'' = I_3 = 2.896 \angle -23.96^\circ$ A .
so:- $I_o = 6.11 \angle -35.21^\circ$ A .

④ :- By using superposition Find Vx :-



$V_s = 50 \cos 2t$ V .
$I_s = 12 \cos(6t+10)$ A .

- Is is on , Vs is off (s.c) :-



- $I = \dfrac{I_s \times [20 + j30]}{20 + j3 + 16}$ current division

$I = \dfrac{12 \angle 10^\circ \times [20 + j30]}{36 + j3}$

$I = 9.23 \angle 26.5^\circ$ A .

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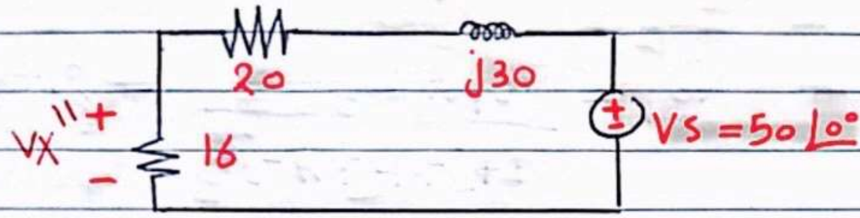
- $V_X' = I \times 16$
$= 9.23 \angle 26.5^\circ \times 16$
$= 147.6 \angle 26.5^\circ$ V.

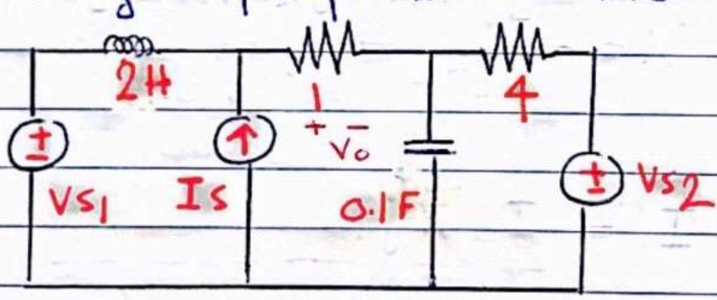
- V_s is on , I_s is off (o.c) :-



- $V_X'' = \dfrac{V_s \times 16}{16 + 20 + j30} = 21.4 \angle -15.5^\circ$ V. voltage division

- $V_X = V_X' + V_X''$
$= 147.6 \cos(6t + 26.5^\circ) + 21.4 \cos(2t - 15.5^\circ)$ V.

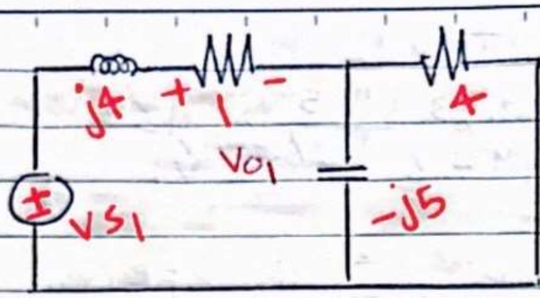
Q :- By using superposition Find V_o :-



$V_{s1} = 10 \cos 2t$ V.
$V_{s2} = 5$V .
$I_s = 2 \sin 5t$.

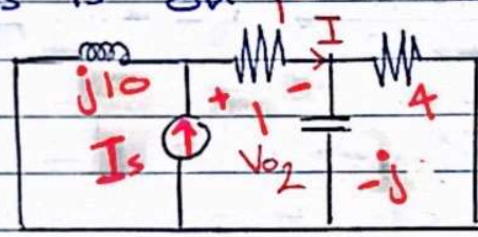
- I_s is off (o.c) , V_{s2} is off (s.c) ,
V_{s1} is on :-

- $X_L = j\omega L = j(2 \times 2) = j4\ \Omega$.
- $X_C = \dfrac{1}{j\omega c} = \dfrac{1}{j(2 \times 0.1)} = -j5\ \Omega$.



Voltage division — $V_{o1} = \dfrac{V_{s1} \times 1}{1 + j4 + [4 \,//\, -j5]} = 2.49 \angle -30.7^\circ \text{ V}$.

— V_{s1} is off (s.c) و V_{s2} is off (s.c) و
I_s is on :-



— $X_L = j\omega L = j(2 \times 5) = j10 \ \Omega$.

— $X_C = \dfrac{1}{j\omega C} = \dfrac{1}{j(5 \times 0.1)} = -j2 \ \Omega$.

— $I = \dfrac{I_s \times j10}{j10 + 1 + [-j2 \,//\, 4]}$ current division

$I = \dfrac{2\angle 0^\circ \times j10}{j10 + 1 + [-j2 \,//\, 4]} = 2.32 \angle -80^\circ \text{ A}$.

— $V_{o2} = I \times 1 = 2.32 \angle -80^\circ \text{ V}$.

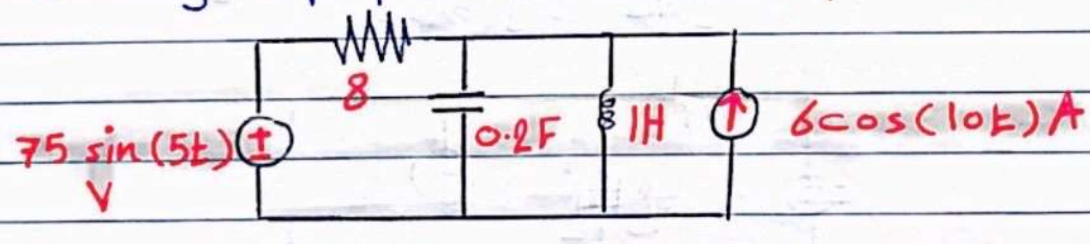
— V_{s1} is off (s.c) و I_s is off (o.c) و
V_{s2} is on :-

- $X_L = j\omega L = j(2 \times 0) = 0$. (s.c)
- $X_c = \frac{1}{j\omega c} = \frac{1}{j(0 \times 0.1)} = \infty$. (o.c)

- $V_{o3} = \frac{-V_{s2} \times 1}{(1+4)} = \frac{-5 \times 1}{5} = -1V$.

- $V_o = V_{o1} + V_{o2} + V_{o3}$
$= 2.49\cos(2t - 30.7) + 2.33\sin(5t + 10) - 1\ V$.

Q :- Calculate Vo in the circuit of the Figure using superposition theorem :-



- V is off (s.c), I is on :-

- $X_L = j\omega L = j(10 \times 1) = j10\ \Omega$.
- $X_C = \frac{1}{j\omega c} = \frac{1}{j(10 \times 0.2)} = -j0.5\ \Omega$.

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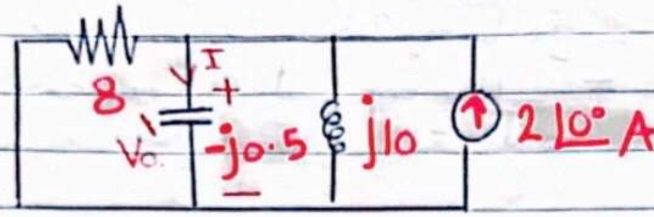


- $Z_{eq} = [8 \,//\, j10] = 6.24 \angle 38.65°$ A.
- $I = \dfrac{I_s \times Z_{eq}}{Z_{eq} + -j0.5} = \dfrac{2\angle 0° \times 6.24\angle 38.65°}{6.24\angle 38.65° + -j0.5}$

$= 6.302 \angle 3.76°$ A.

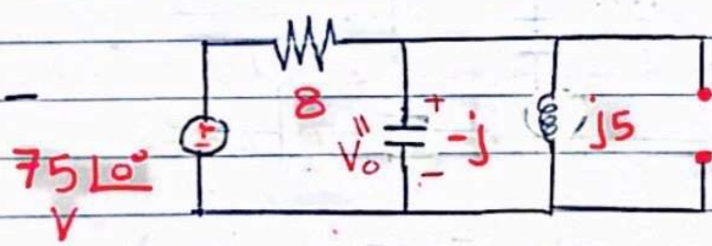
- $V_o' = I \times -j0.5$

$= 6.302\angle 3.76° \times -j0.5$

$= 3.15 \angle -86.23°$ V.

- I is off (o.c) و V is on

- $X_L = j\omega L = j(5 \times 1) = j5\ \Omega$.
- $X_C = \dfrac{1}{j\omega C} = \dfrac{1}{j(5 \times 0.2)} = -j\ \Omega$.

- 

- $Z_{eq} = [j5 \,//\, -j] = -j1.25\ \Omega$.

- $V_o'' = \dfrac{75\angle 0° \times Z_{eq}}{Z_{eq} + 8} = \dfrac{75\angle 0° \times -j1.25}{-j1.25 + 8}$

$= 11.57 \angle -81.12°$ V.

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$$- \quad V_o = V_o' + V_o''$$
$$= 3.15 \cos(10t - 86.23^\circ) + 11.57 \sin(5t - 81.12^\circ).$$

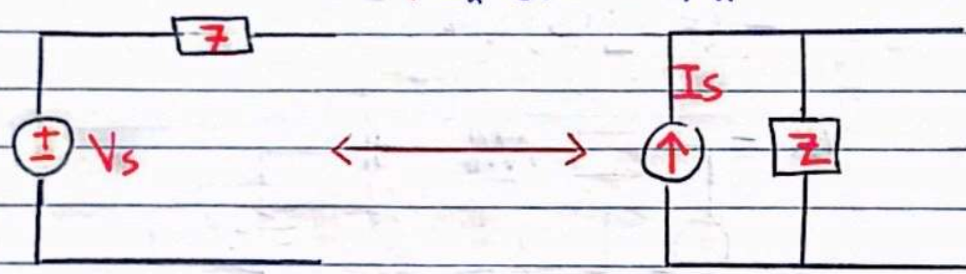
∴ Note :-

يجب الانتباه إلى قيمة [W] في كل مصدر ، أي اختلاف قيمة التردد ، وهذا يعني انه عند الانتهاء من حساب التيار او الجهد المطلوب لا يتم جمعهم كقيم عددية .

- Source transformation :-

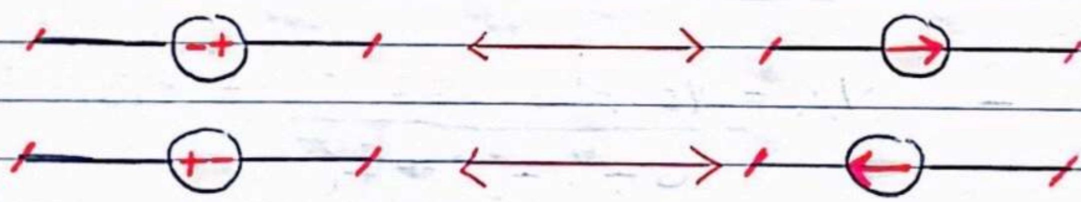
* في هذه الحالة يتم التحويل بين :-

*

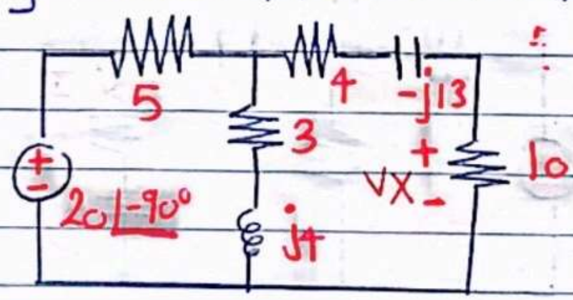


$$V_s = Z I_s \qquad\qquad I_s = \frac{V_s}{Z}$$

*



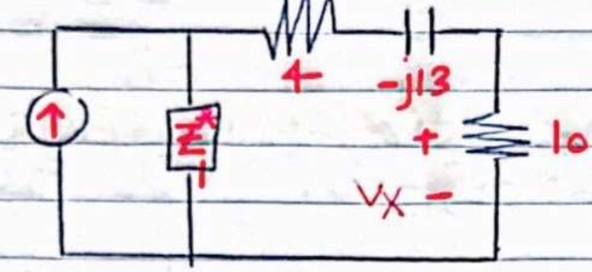
① :- By using source transformation, find Vx :-



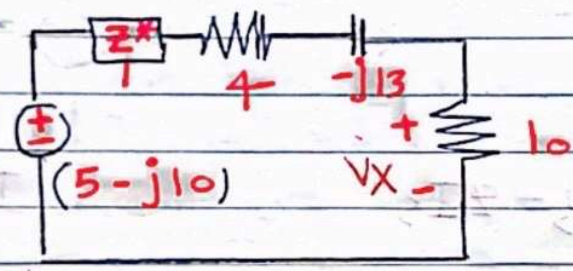
$$- \quad I_s = \frac{V_s}{Z} = \frac{20\angle -90^\circ}{5} = 4\angle -90^\circ \ A.$$

$$- \quad Z^* = \left[5 \,//\, [3 + j4]\right]$$

$$Z_1^* = \frac{5 \times (3+j4)}{5+3+j4} = 2.5 + j1.25 \ \Omega.$$

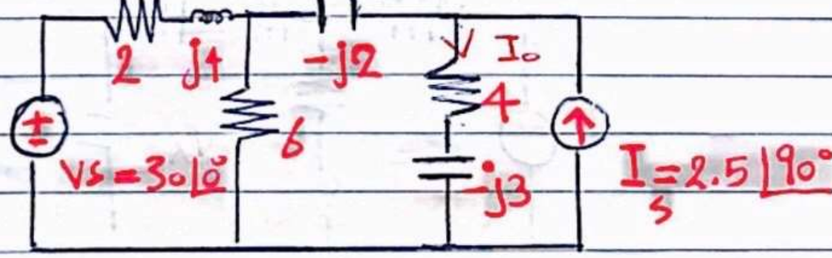


- $V_s = I_s \times Z_1^*$
  $= -j4 \times (2.5 + j1.25)$
  $= (5 - j10)\ V.$



- $$V_X = \frac{V_s \times 10}{10 + 4 - j13 + Z_1^*} = 5.519 \angle -28^\circ \ V.$$

④ :- using source transformation to find I_o :-



- $Zeq_{L1} = [2 + j4]\ \Omega.$

- $$I_1^* = \frac{V_s}{Zeq_{L1}} = \frac{30 \angle 0^\circ}{(2+j4)} = 6.7 \angle -63.4^\circ \ A.$$

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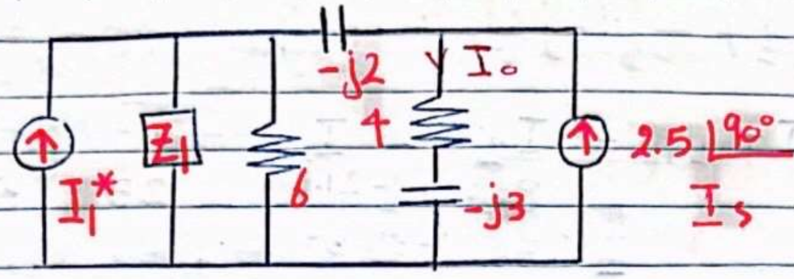
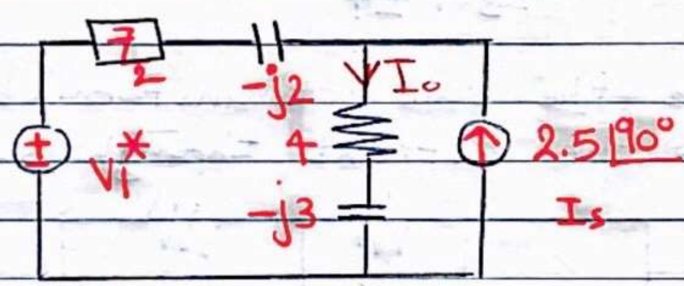


$$Z_{eq2} = [Z_{eq1} \,//\, 6] = [2+j4] \,//\, 6$$
$$= \frac{[2+j4]\times 6}{2+j4+6} = [2.4+j1.8]\ \Omega .$$

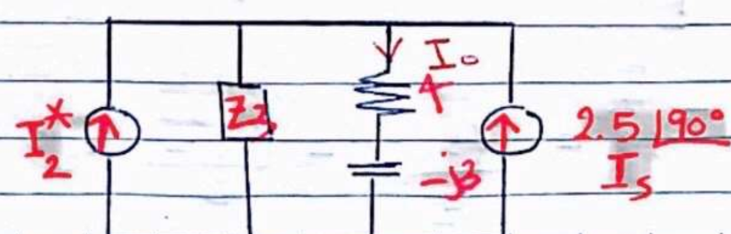
$$V_1^* = I_1^* \times Z_{eq2}$$
$$= 6.7\angle{-63.4^\circ} \times [2.4+j1.8]$$
$$= 20.1\angle{-26.53^\circ}\ V .$$



$$Z_{eq3} = Z_{eq2} + -j2 = 2.4+j1.8-j2$$
$$= [2.4 - j0.2]$$

$$I_2^* = \frac{V_1^*}{Z_{eq3}} = \frac{20.1\angle{-26.53^\circ}}{[2.4-j0.2]}$$

$$= 8.35\angle{-21.7^\circ}\ A .$$

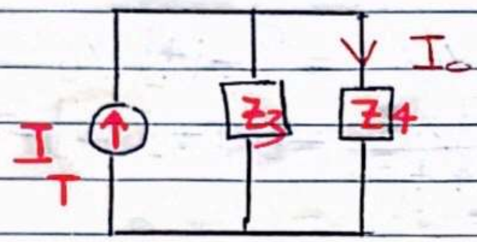


- $Z_{eq4} = [4 - j3]\ \Omega$.

- $I_{Total} = I_2^* - I_s$ → طرح لأنهم عكس اتجاه بعض

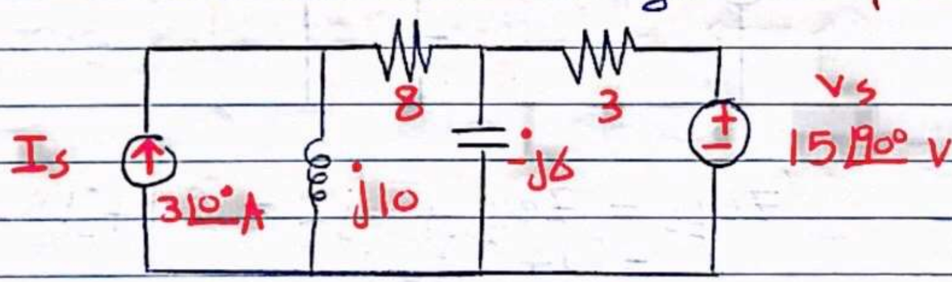
$= 8.35\angle{-21.7^\circ} - 2.5\angle{90^\circ}$

$= 9.56\angle{-35.8^\circ}\ A$.

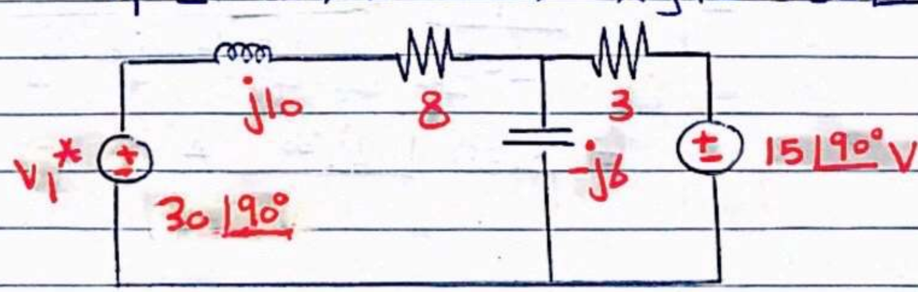
- 

- $I_o = \dfrac{I_T \times Z_3}{Z_3 + Z_4} = 3.21\angle{-13.99^\circ}\ A$.

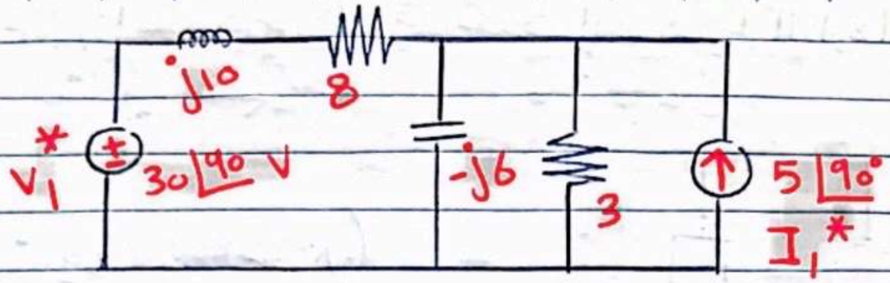
④ :- Use the source transformation to find the current through $8\ \Omega$:-



- $V_1^* = I \times Z = 3\angle{0^\circ} \times j10 = 30\angle{90^\circ}\ V$.

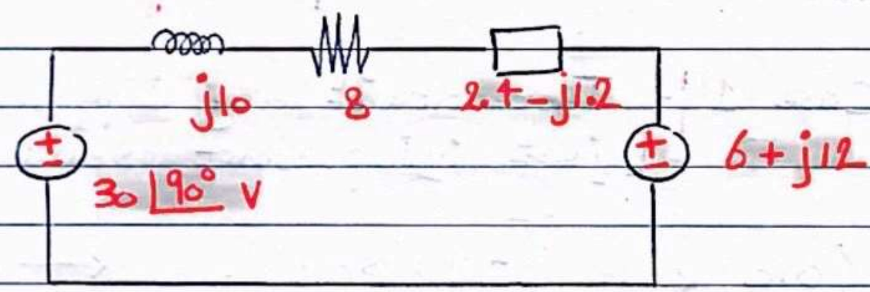
- 

- $I_1^* = \dfrac{V_s}{Z} = \dfrac{15\angle{90^\circ}}{3} = 5\angle{90^\circ}\ A$.



- $Z_{eq1} = [-j6 \,//\, 3] = [2.4 - j1.2]\ \Omega$.

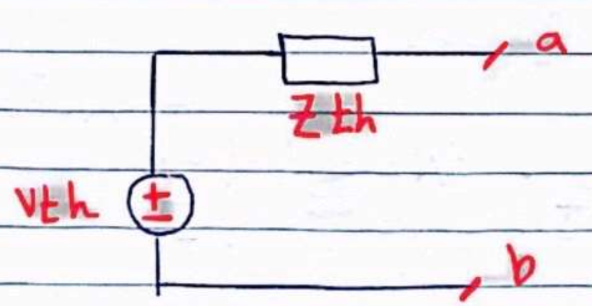
- $V = I_1^* \times Z_{eq1}$
  $= 5\angle 90° \times [2.4 - j1.2]$
  $= [6 + j12]$.



- KVL at the Loop :-
  $-30\angle 90° + [j10 + 8 + 2.4 - j1.2]\, I + [6 + j12] = 0$
  $I = 1.39\angle 88.19°$ A.

- Thevenin and Norton equivalent circuit :-

* Thevenin :- وهي نظرية تهدف إلى تحويل الدارة المعقدة إلى الشكل التالي ←



(Thevenin equivalent circuit)

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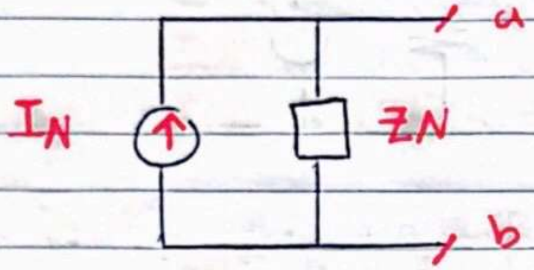
* Norton :- وهي نظرية تهدف إلى تحويل الدارة المعقدة إلى الشكل التالي ←



(Norton equivalent circuit)

- $Z_N = Z_{th}$
- $V_{th} = Z_{th} \times I_N$

- There are 3 cases :-

[1] Case 1 :- There aren't any dependent sources, [just independent sources].

مصدر الجهد ← (s.c) ، مصدر التيار ← (o.c)

- طريقة الحل :-

* Thevenin :-

1) حساب Z_{th} : وهذا يتم عن طريق إزالة جميع [independent sources] ومن ثم حساب Z_{th}.

2) حساب V_{th} :- وهذا يتم بعد إعادة المصادر التي حذفت ، وحساب V_{th} بين طرفي Thevenin المحدد بالسؤال بالطرق التي أخذناها سابقًا.

* Norton :-

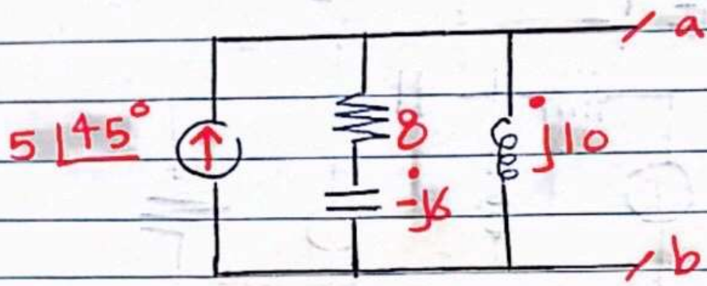
1) حساب Z_N :- $Z_N = Z_{th}$.

2) حساب I_N :- $I_N = \dfrac{V_{th}}{Z_{th}}$.

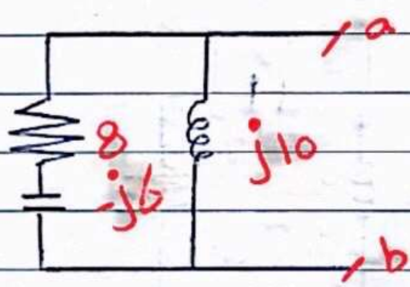
∴ Note :-

في حال وجود [ZL] بين طرفي ← [Norton or Thevenin]
تحذفها و نستخدم فقط في حال طلب التيار أو الجهد على هذا ال
[Load] .

Q :- Find the thevenin equivalent of the circuit in the Figure :-



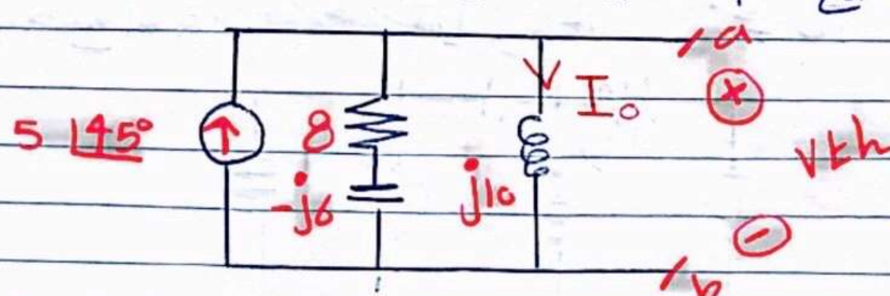
- To Find Zth, remove all independent sources :-



- $Z_{th} = [8-j6] \parallel j10$

$$= \frac{8-j10 \times j10}{8-j10+j10} = 11.8 \angle 26.56^\circ \ \Omega .$$

- To Find Vth, [نعيد جميع المصادر التي حذفت] :-

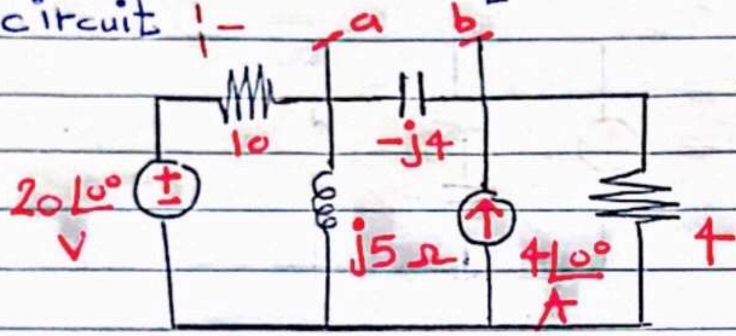


$$- \; I_o = \frac{I_s \times [8 - j6]}{8 - j6 + j10} = \frac{5\angle 45^\circ \times [8 - j6]}{8 - j6 + j10}$$

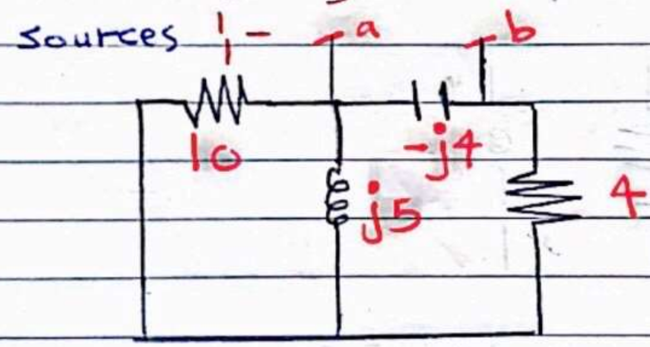
$$= [5.3 - j1.77] \; A.$$

$$- \; V_{th} = I_o \times j10 = 55.9 \angle 71.56^\circ \; V.$$

4 :- Find the thevenin equivalent of the circuit :-



- To Find Zth , remove all independent sources :-

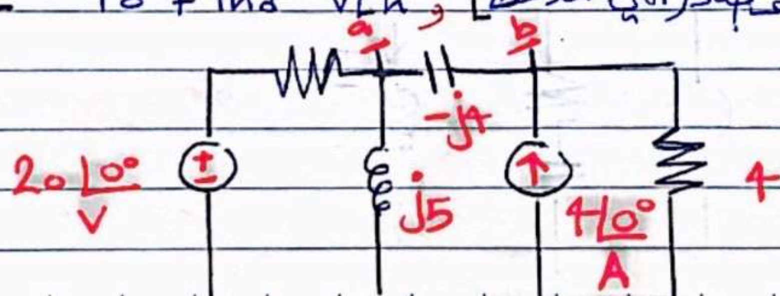


$$- \; Z_{eq1} = [10 \,//\, j5] = [2 + j4] \; \Omega.$$

$$- \; Z_{eq2} = 2 + j4 + 4 = [6 + j4] \; \Omega.$$

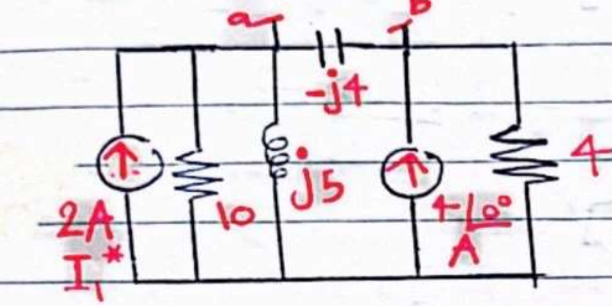
$$- \; Z_{th_1} = [6 + j4] \,//\, -j4 = [2.667 - j4] \; \Omega.$$

- To Find Vth , [نعيد جميع المصادر التي حذفتها] :-

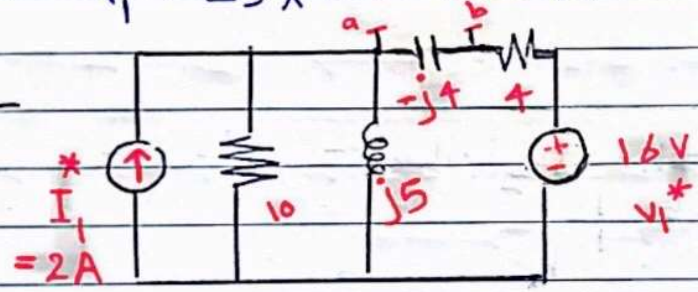


- By using source transformation :-

- $I_1^* = \frac{V_s}{Z} = \frac{20\angle 0^\circ}{10} = 2\angle 0^\circ\ A$.

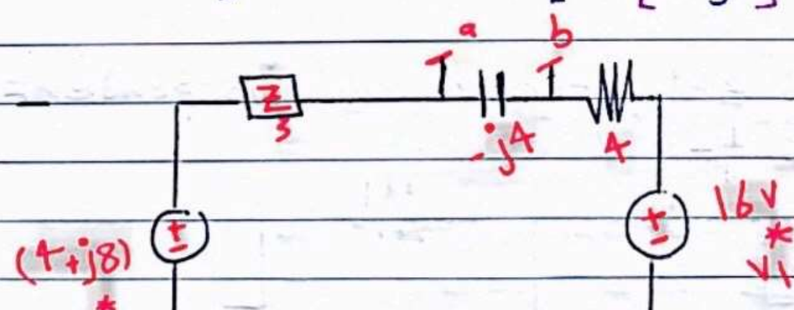


- $V_1^* = I_s \times Z = 4\angle 0^\circ \times 4 = 16\ V$.



- $Z_{eq_{Z_3}} = [10 \,//\, j5] = [2+j4]\ \Omega$.

- $V_2^* = I_1^* \times Z_{eq_3} = [2+j4] \times 2 = [4+j8]\ V$.



- KVL at the loop :-

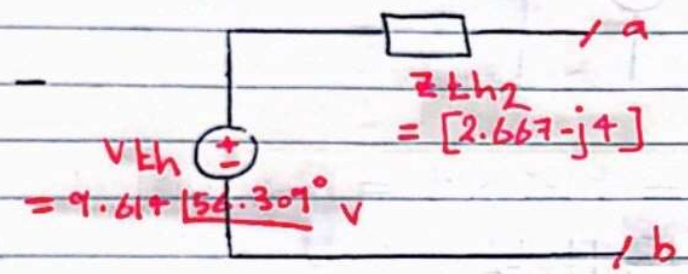
$-[4+j8] + [Z_3 - j4 + 4]\, I + 16 = 0$

$I = 2.4\angle 146.304^\circ\ A$.

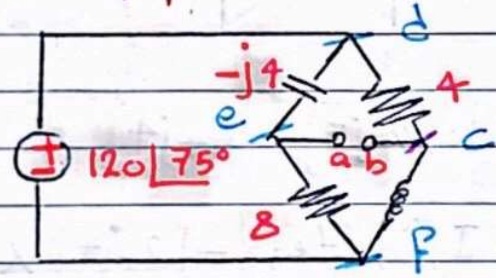
- $V_{ab} = I \times -j4 = 9.614 \angle 56.309^\circ \, V$.

- $Zth_2 = -j4 + 4 + Zeq_3$
  $= [2.667 - j4] \, \Omega$.

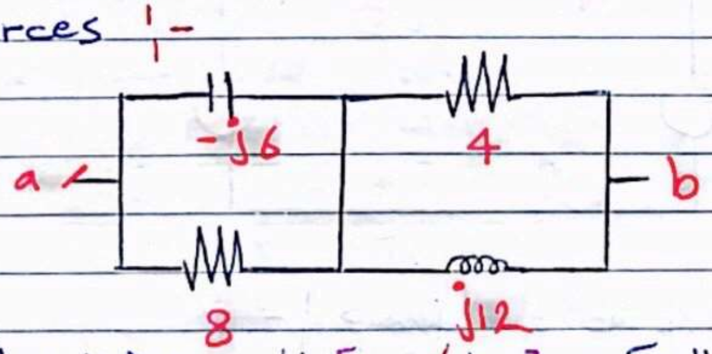
- $I_N = \dfrac{V_{th}}{Z_{th}} = \dfrac{V_{ab}}{Z_{th}} = 2 \angle 112.6^\circ A$.

- 

Q :- obtain the eqivalent circuit at terminals (a-b) :-



- To Find zth, remove all independent sources :-



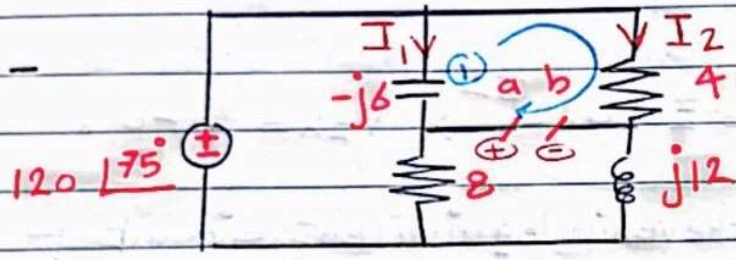
قلبنا السلكين [ea / bc] إلى خارج الدارة الكهربائية.

- $Z_1 = [-j6 \parallel 8] = \dfrac{-j6 \times 8}{-j6+8} = [2.88 - j3.84]\ \Omega$.

- $Z_2 = [j12 \parallel 4] = \dfrac{j12 \times 4}{j12+4} = [3.6 + j1.2]\ \Omega$.

- $Z_{th} = Z_1 + Z_2 = [6.48 - j2.64]\ \Omega$.

- To Find V_{th} [نعيد جميع المصادر التي حذفت] و :-



- $I_1 = \dfrac{120\angle 75^\circ}{[-j6+8]} = 12\angle 111.86^\circ\ A$.

- $I_2 = \dfrac{120\angle 75^\circ}{[4+j12]} = 9.4868\angle 3.43^\circ\ A$.

- KVL at Loop 1 :-

$$-j6I_1 + 4I_2 + V_{th} = 0$$

$$V_{th} = 37.9\angle 220.31^\circ\ V$$.

[2] Case 2 :- There are dependent sources و
[No independent sources] .

∴ Note :- دائماً قيمة [V_{th} = Zero] لأن الدارة لا
تحتوي على [independent sources] .

- طريقة الحل :-

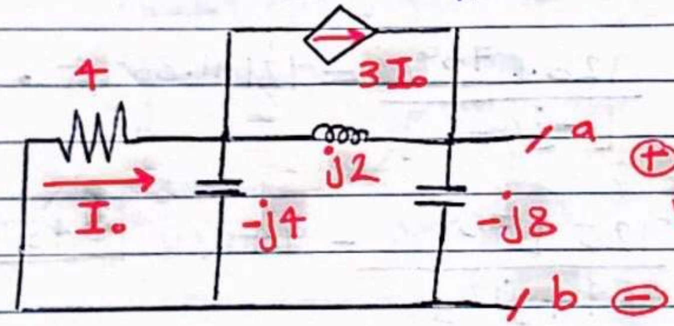
- لحساب Z_{th} :- إضافة مصدر جهد أو مصدر تيار غير معتمد ، نفرض قيمتهم [1A / 1V] على التوالي ، يوصل المصدر بين طرفي الـ [Thevenin] ، ثم نقوم بحل الدارة لإيجاد التيارات الشمولية على المصدر الذي فرضناه .

- وتكون قيمة Z_{th} :-

* إذا فرضنا مصدر تيار قيمته 1A / $Z_{th} = \frac{V}{I} = V$.
* إذا فرضنا مصدر جهد قيمته 1V / $Z_{th} = \frac{V}{I} = \frac{1}{I}$.

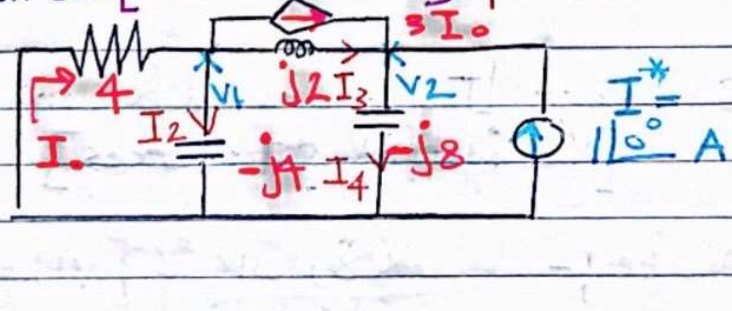
∴ Note :- $I_N = Zero \xrightarrow{\text{لأن}} V_{th} = Zero$.

① :- Find the thevenin equivalent circuit :-



- $V_{th} = Zero$.

- To Find Z_{th} , We add a current source [$I^* = 1\angle 0^\circ$ A] :-



- KCL at node 1 :-

$$I_o = 3I_o + I_2 + I_3$$

$$\frac{0-V_1}{4} = 3\left[\frac{0-V_1}{4}\right] + \frac{V_1}{-j4} + \left[\frac{V_1-V_2}{j2}\right]$$

$$\frac{0-V_1}{4} = \frac{-3V_1}{4} + \frac{V_1}{-j4} + \frac{V_1}{j2} + \frac{-V_2}{j2}$$

$$V_1\left[\frac{1}{4} - \frac{3}{4} + \frac{1}{-j4} + \frac{1}{j2}\right] + \frac{-V_2}{j2} = 0$$

$$\left(V_1\left[\frac{1}{4} - \frac{3}{4} + \frac{j}{4} - \frac{j}{2}\right] + \frac{jV_2}{2} = 0\right) \times 4$$

$$[-2-j]V_1 + j2V_2 = 0 \quad \dots (1)$$

- KCL at node 2 :-

$$I^* + 3I_o + I_3 = I_4$$

$$1\angle 0^\circ + 3\left[\frac{0-V_1}{4}\right] + \left[\frac{V_1-V_2}{j2}\right] = \frac{V_2}{-j8}$$

$$1\angle 0^\circ + \frac{-3V_1}{4} + \frac{V_1}{j2} - \frac{V_2}{j2} = \frac{V_2}{-j8}$$

$$\frac{-3}{4}V_1 + \frac{V_1}{j2} + \frac{-V_2}{j2} - \frac{V_2}{-j8} = -1\angle 0^\circ$$

$$V_1\left[\frac{-3}{4} + \frac{1}{j2}\right] + V_2\left[\frac{-1}{j2} \; \frac{-1}{-j8}\right] = -1$$

$$\left(V_1\left[\frac{-3}{4} - \frac{j}{2}\right] + V_2\left[\frac{j}{2} - \frac{j}{8}\right] = -1\right) \times 8$$

$$[-6-j4]V_1 + j3V_2 = -8 \quad \dots (2)$$

- By [carmer's rule] :-

$$V_1 = 2.63\angle 99.46^\circ \text{ V}.$$

$$V_2 = 2.94\angle -53.97^\circ \text{ V}.$$

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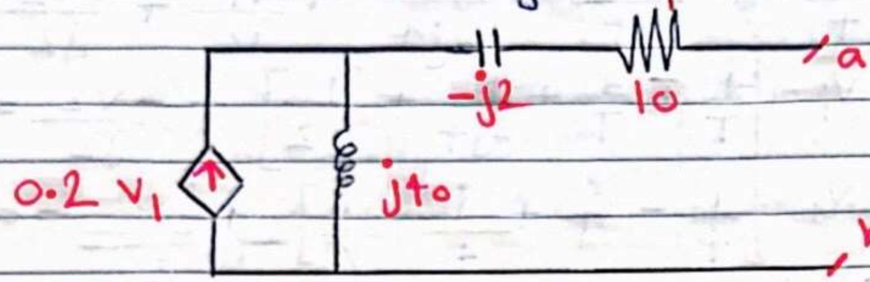
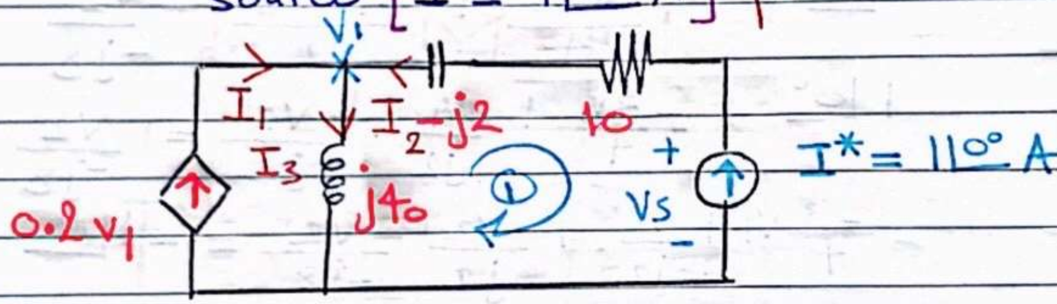
$$- \; Z_{th} = \frac{V_{th}}{I^*} = \frac{V_2}{1} = 2.94 \angle -53.97^\circ \, \Omega.$$

Q:- Calculate the output impedence of the circuit in the figure :-



- $V_{th} = $ Zero.

- To find Z_{th}, we add a current source $[I^* = 1 \angle 0^\circ \, A]$:-



- KCL at the node :-

$$I_1 + I_2 = I_3$$

$$0.2V_1 + 1 = \frac{V_1}{j40}$$

$$V_1 = [-16 + j40] \, V.$$

- KVL at Loop 1 :-

$$-V_{j40} + V_{-j2} + V_{10} + V_S = 0$$

$$-V_1 + [-1 \times -j2] + [10 \times -1] + V_S = 0$$

$$-[-16 + j40] + j2 - 10 + V_S = 0$$

$$V_s = [-6 + j38]\ V .$$

$$- \quad Z_{th} = \frac{V_s}{I^*} = \frac{[-6+j38]}{1} = [-6+j38]\ \Omega .$$

3 Case 3 :- [There are dependent sources and independent sources] :-

- طريقة الحل :-

- نحسب Zth :- أولاً نحذف كل [independent sources] ، ومن ثم نقوم بإضافة مصدر جهد أو مصدر تيار غير معتمد ، نفرض قيمتهم [1A / 1V] على التوالي ، يوصل المصدرين طرفي الـ [Thevenin] ، ثم نقوم بحل الدارة لإيجاد التيار أو الفولتية عن المصدر الذي فرضناه .

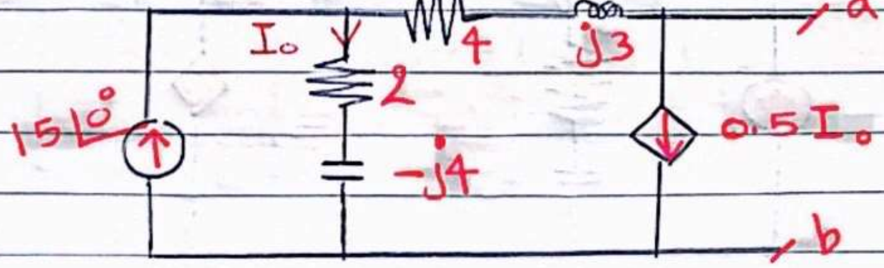
- وتكون قيمة Zth :-

* إذا فرضنا مصدر تيار قيمته 1A / $Z_{th} = \frac{V}{I} = V$.

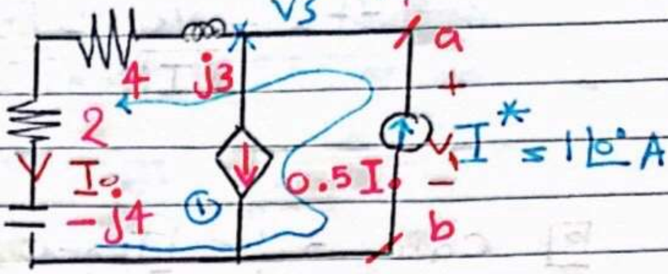
* إذا فرضنا مصدر جهد قيمته 1V / $Z_{th} = \frac{V}{I} = \frac{1}{I}$.

- نحسب Vth :- نقوم بإرجاع المصادر المحذوفة ، ومن ثم إزالة مصدر الجهد أو التيار المفروض ، ومن ثم حسابها بالطرق المذكورة سابقاً .

1 :- Find [Vth and Zth] between (a-b) :-



- To Find Zth, Remove all independent sources, then add a current source $[I^* = 1\angle 0^\circ\ A]$:-



- KCL at node Vs :-

$$I_o + 0.5 I_o = I^*$$
$$1.5 I_o = 1\angle 0^\circ$$
$$I_o = 0.667\ A.$$

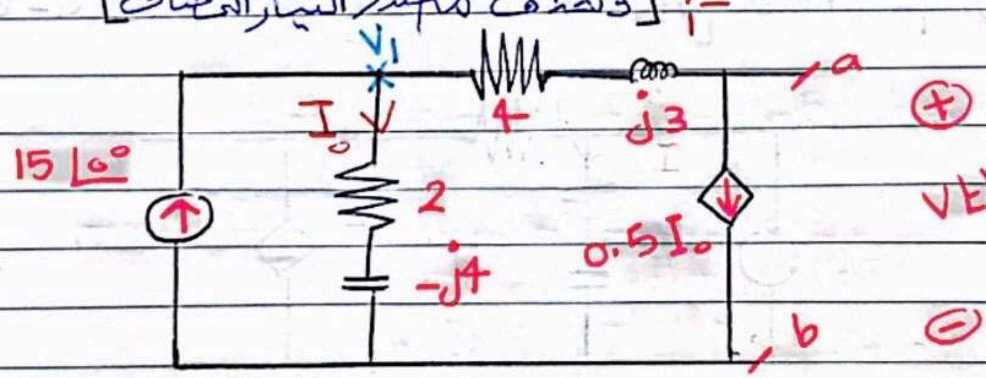
- KVL at Loop 1 :-

$$-V_1 + [4 + j3] I_o + [2 - j4] I_o = 0$$
$$V = [4 - j0.667]\ V$$
$$= 4.055\angle -9.466^\circ\ V.$$

- To Find Zth :-

$$Zth = \frac{V_1}{I^*} = \frac{4.055\angle -9.466^\circ}{1\angle 0^\circ}$$
$$= 4.055\angle -9.466^\circ\ \Omega.$$

- To Find Vth, [نعيد جميع المصادر التي حذفت], [ونحذف مصدر التيار المضاف] :-



- To find I_o, KCL at node 1 :-

$$15\angle 0^\circ = 0.5\, I_o + I_o$$

$$1.5\, I_o = 15\angle 0^\circ$$

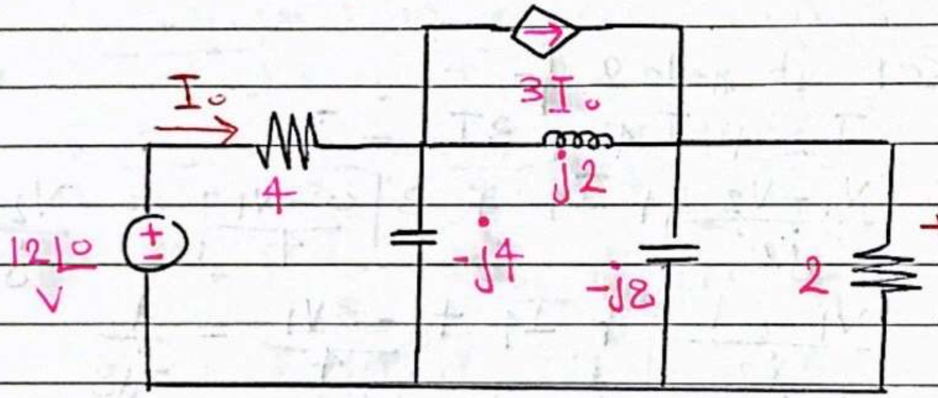
$$I_o = 10\,A \,.$$

- To find Vth, KVL at Loop 1 :-

$$-V_{th} + -[4+j3] \times 0.5\, I_o + [2-j4]\, I_o = 0$$

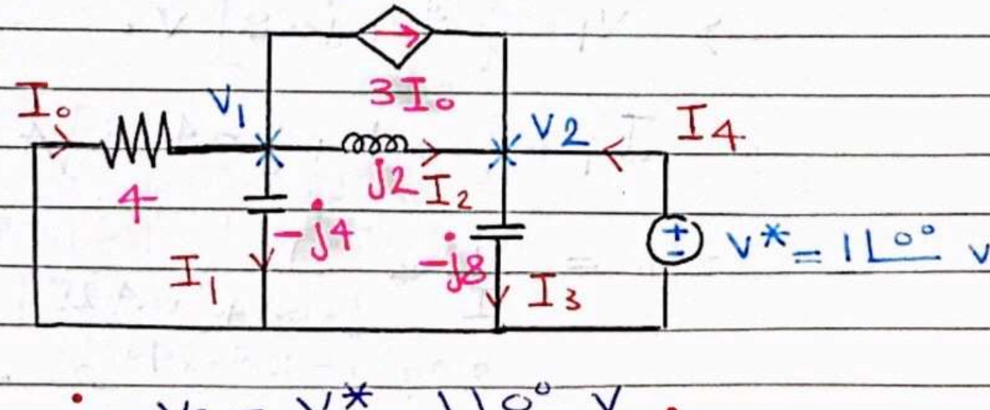
$$V_{th} = 55\angle -90^\circ \; V \,.$$

Q :- By using Thevenin theorem, Find Vo in the circuit :-



بما أنه طلب حساب الفولتية عبر [2Ω] فإنها تحذف في جميع الخطوات ونستخدم آخر شي .

- To find Zth, Remove all independent sources, then add a voltage source $[V^* = 1\angle 0^\circ\, V]$:-



$$\therefore\; V_2 = V^* = 1\angle 0^\circ \; V \,.$$

- KCL at node 1 :-

$$I_o = 3I_o + I_1 + I_2$$

$$\frac{0-V_1}{4} = 3\left[\frac{0-V_1}{4}\right] + \frac{V_1}{-j4} + \frac{V_1-V_2}{j2}$$

$$\frac{-V_1}{4} = \frac{-3V_1}{4} + \frac{V_1}{-j4} + \frac{V_1}{j2} + \frac{-V_2}{j2}$$

$$\frac{V_1}{4} - \frac{3V_1}{4} + \frac{V_1}{-j4} + \frac{V_1}{j2} + \frac{-1}{j2} = 0$$

$$\times 4 - \left(V_1 \left[\frac{1}{4} - \frac{3}{4} + \frac{j}{4} - \frac{j}{2} + \frac{j}{2}\right] + \frac{j}{2} = 0 \right)$$

$$V_1 = [0.4 + j0.8]\ V.$$

- KCL at node 2 :-

$$I_2 + I_4 + 3I_o = I_3$$

$$\left[\frac{V_1-V_2}{j2}\right] + I_4 + 3\left[\frac{0-V_1}{4}\right] = \frac{V_2}{-j8}$$

$$\left[\frac{V_1-1}{j2}\right] + I_4 + \frac{-3V_1}{4} = \frac{1}{-j8}$$

$$\frac{V_1}{j2} + \frac{-1}{j2} + I_4 - \frac{3V_1}{4} = \frac{1}{-j8}$$

$$I_4 = \frac{1}{-j8} + \frac{1}{j2} - \frac{V_1}{j2} + \frac{3V_1}{4}$$

$$I_4 = \frac{j}{8} + \frac{-j}{2} + V_1\left[\frac{j}{2} + \frac{3}{4}\right]$$

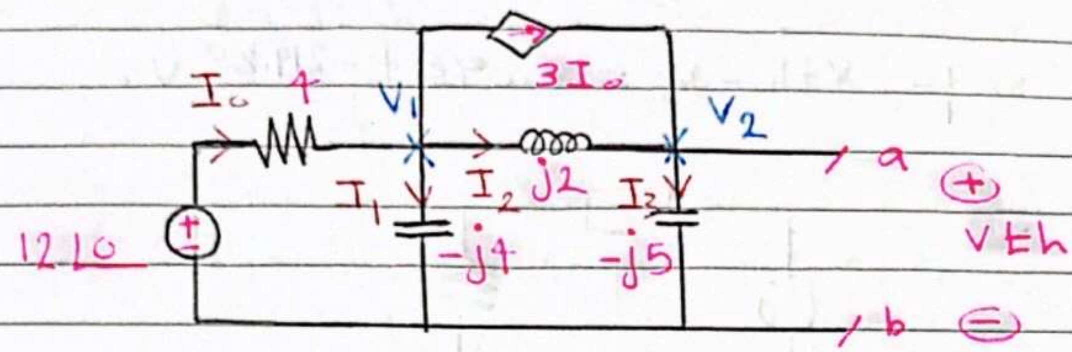
$$\rightarrow V_1 = [0.4 + j0.8]\ V.$$

$$I_4 = [-0.1 + j0.425]\ A.$$

- $$Z_{th} = \frac{V}{I} = \frac{1}{[-0.1 + j0.425]}$$

$$= 2.29 \angle -103.24^\circ\ \Omega.$$

- To Find V_{th} و [نعيد جميع المصادر التي حذفت] و
[ونحذف مصدر الجهد المضاف] :-



- KCL at node 1 :-

$$I_o = 3I_o + I_1 + I_2$$

$$\left[\frac{12 - V_1}{4}\right] = 3\left[\frac{12 - V_1}{4}\right] + \frac{V_1}{-j4} + \left[\frac{V_1 - V_2}{j2}\right]$$

$$\frac{12}{4} - \frac{V_1}{4} = \frac{36}{4} - \frac{3V_1}{4} + \frac{V_1}{-j4} + \frac{V_1}{j2} - \frac{V_2}{j2}$$

$$\times 4 \left(V_1\left[\frac{1}{-j4} - \frac{3}{4} + \frac{1}{4} + \frac{1}{j2}\right] - \frac{V_2}{j2} = -6 \right)$$

$$[2+j]V_1 + -j2V_2 = 24 \quad \dots (1)$$

- KCL at node 2 :-

$$3I_o + I_2 = I_3$$

$$3\left[\frac{12 - V_1}{4}\right] + \left[\frac{V_1 - V_2}{j2}\right] = \frac{V_2}{-j5}$$

$$\frac{36}{4} - \frac{3V_1}{4} + \frac{V_1}{j2} - \frac{V_2}{j2} = \frac{V_2}{-j5}$$

$$V_1\left[-\frac{3}{4} + \frac{1}{j2}\right] + V_2\left[-\frac{1}{j2} - \frac{1}{-j5}\right] = -9$$

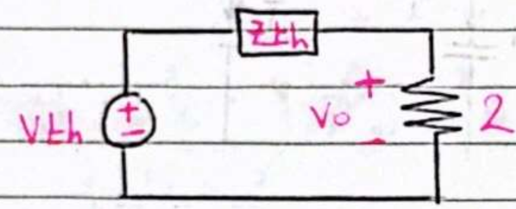
$$[6+j4]V_1 + -j3V_2 = 72 \quad \dots (2)$$

- By [carmer's rule] :-

$V_1 = 9.218 \angle -39.8^\circ \ V$.

$V_2 = 3.073 \angle -219.8^\circ \ V$.

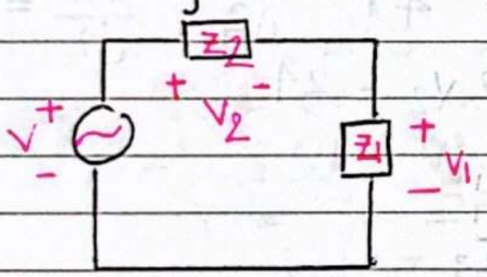
sol:- $V_{th} = V_2 = 3.073 \angle -219.8^\circ \ V$.



- $V_o = \dfrac{V_{th} \times 2}{Z_{th} + 2} = 2.3 \angle -163.3^\circ \ V$.

∴ Note :-

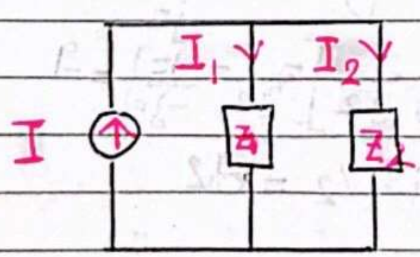
- Voltage divider :-



- $V_1 = \dfrac{V \times Z_1}{Z_1 + Z_2}$

- $V_2 = \dfrac{V \times Z_2}{Z_1 + Z_2}$

- Current divider :-



- $I_1 = \dfrac{I \times Z_2}{Z_1 + Z_2}$

- $I_2 = \dfrac{I \times Z_1}{Z_1 + Z_2}$

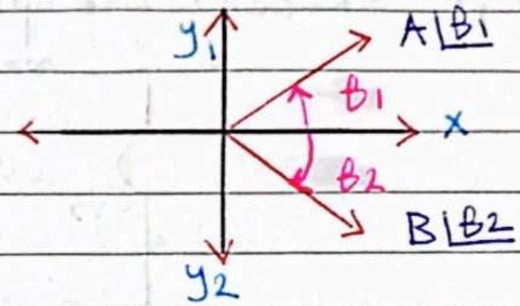
- Phasor diagram :-

هو عبارة عن [Sketch] يتم فيه رسم الـ [voltage/current] لجميع الـ [terminals] الموجودة في الدارة الكهربائية [Resistors / inductors / capacitors].

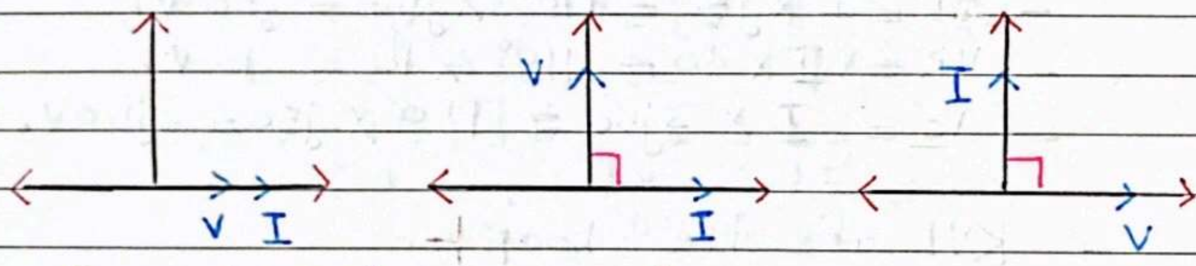
- Sketch in a complex plane :-

$X + jy_1 = A\angle\theta_1$

$X + jy_2 = B\angle\theta_2$



- [Leading and Lagging] :-



R → (V & I) are in phase. $\theta = 0°$

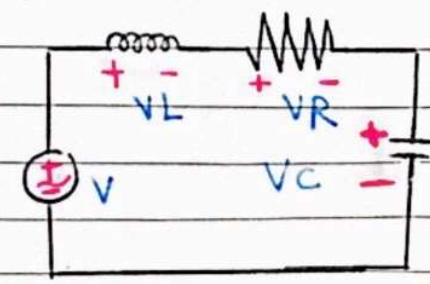
L → (V Leads I or I Lags V). $\theta = 90°$ ⇒ [إذا كانت الدارة RL cct]

C → (V Lags I or I Leads V). $\theta = 90°$ ⇒ [إذا كانت الدارة Rc cct]

* هلا حتى اعرف احل السؤال الخاص بالـ [phasor diagram] لازم احدد الـ [refrence] يعني يا بكون (voltage) or (current).

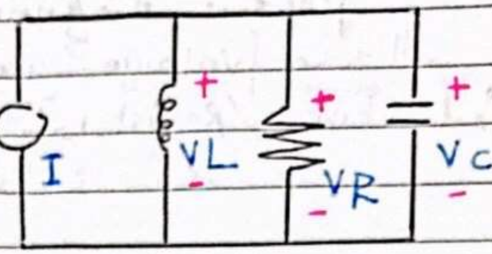
- RLC in series :-
For series I as refrence.

نفرضه $I = 1\angle 0°$ A

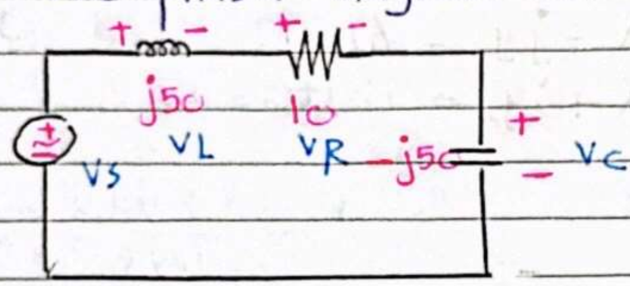


إعداد:-م.سجى البزايعه

- RLC in parallel :-
For parallel V as refrence.
نفرضه $V = 1\angle 0^\circ$ V

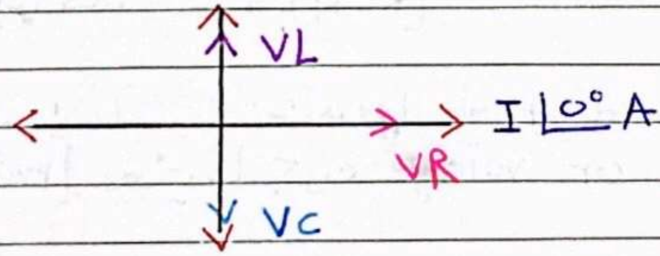


Q :- sketch the phasor diagram for RLC cct :-

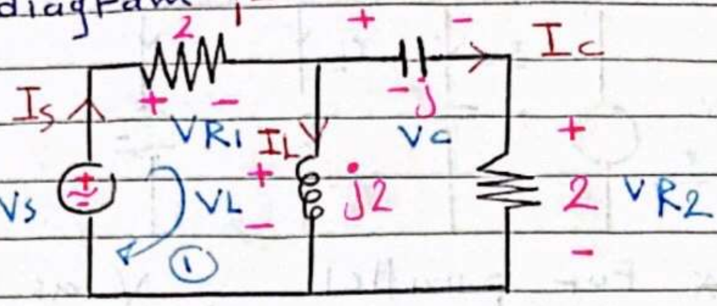


* For series → I as reference, $I = 1\angle 0^\circ$ A.
- $V_L = I \times j50 = 1\angle 0^\circ \times j50 = j50$ V.
- $V_R = I \times 10 = 1\angle 0^\circ \times 10 = 10$ V.
- $V_C = I \times -j50 = 1\angle 0^\circ \times -j50 = -j50$ V.

- KVL at the Loop :-
$-V_S + V_L + V_R + V_C = 0$
$V_S = [j50 + -j50 + 10]$
$V_S = 10$ V.

-


Q :- Choose I_c as a reference, draw a phasor diagram :-



- $I_c = 1\angle 0^\circ$ A
- $V_c = -j \times I_c = -j \times 1\angle 0^\circ = -j$ V.
- $V_{R2} = 2 \times I_c = 2 \times 1\angle 0^\circ = 2$ V.
- $V_L = V_c + V_{R2} = [-j+2]$ V.

لأن [[R2+C]//L] ، والجهد بالتوصيل على التوازي متساوي ، فجهد [L] هو حاصل جمع جهدي [C+R2] .

- $I_L = \frac{V_L}{L} = \frac{[2-j]}{j2} = 1.11\angle -116.56^\circ$ A
- $I_s = I_c + I_L = 1\angle 0^\circ + 1.11\angle -116.56^\circ$
  $= 1.11\angle -63.1^\circ$ A.
- $V_{R1} = 2 \times I_s = 2 \times 1.11\angle -63.1^\circ = 2.22\angle -63.1^\circ$ V.
- To Find V_S, KVL at Loop 1 :-

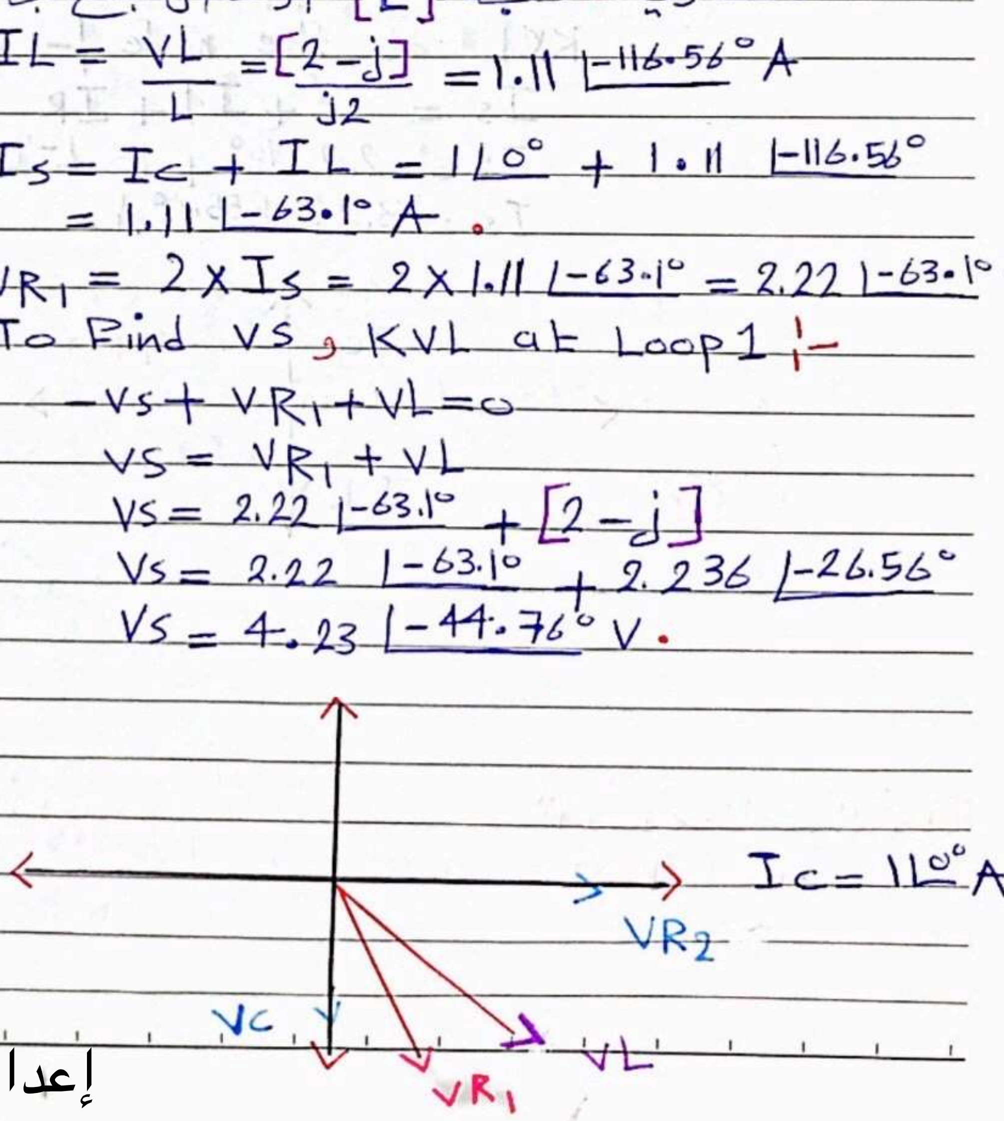
$-V_s + V_{R1} + V_L = 0$

$V_S = V_{R1} + V_L$

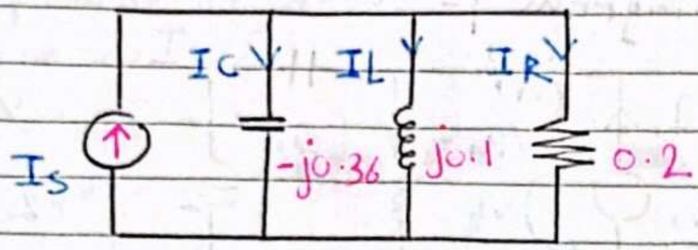
$V_S = 2.22\angle -63.1^\circ + [2-j]$

$V_s = 2.22\angle -63.1^\circ + 2.236\angle -26.56^\circ$

$V_s = 4.23\angle -44.76^\circ$ V.



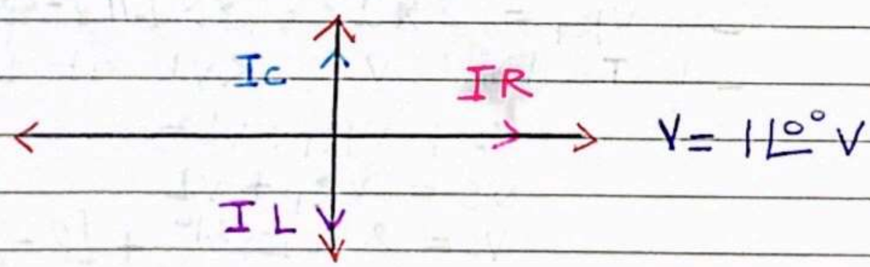
① :- sketch the phasor diagram for RLC cct :-



* For parallel → V as a reference,
$V = 1\angle 0^\circ$ V.

- $I_C = \dfrac{V}{-j0.36} = \dfrac{1\angle 0^\circ}{-j0.36} = 2.7\angle 90^\circ$ A.
- $I_L = \dfrac{V}{j0.1} = \dfrac{1\angle 0^\circ}{j0.1} = 10\angle -90^\circ$ A.
- $I_R = \dfrac{V}{0.2} = \dfrac{1\angle 0^\circ}{0.2} = 5$ A.
- KCL at the node :-

$I_s = I_C + I_L + I_R$
$I_s = 2.7\angle 90^\circ + 10\angle -90^\circ + 5$
$I_s = 8.84\angle -55.6^\circ$ A.



تذوب مخاوف الرحلة
في أمان الله ♡

إعداد:-م.سجى البزايعه

CH :- "AC power analysis" :-

- Average and RMS value :-

* Average value :- القيمة المتوسطة .

- Average value For any [periodic function [y(t)]] :-

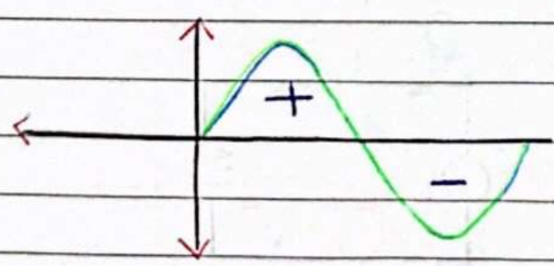
$$y_{avg} = \frac{1}{T}\int_0^T y(t).dt$$

- Average value for [sinusoidal functions [y(t)]] :-

$$y_{avg} = \frac{1}{2\pi}\int_0^{2\pi} y(t).dt = Zero$$

→ $T = 2\pi$ [For sinusoids] .

∴ Note :-
Why [yavg = Zero] for [sinusoids] ?
because the sinusoidal functions are half symmetry Functions .



"Half wave symmetry"
[الموجة الموجبة = الموجة السالبة]
بجذفوا بعض .

وهذا ينطبق على أي نوع من أنواع الموجات ، إذا كانت الموجة الموجبة مساوية للموجة السالبة .

إعداد:-م.سجى البزايعه

* Effective value, [RMS value] Root mean square value :- القيمة الفعّالة.

$$y_{RMS} = y_{eff} = \sqrt{\frac{1}{T}\int_0^T y^2(t)\cdot dt}$$

لكي نتخلص من الجذر [نربع الطرفين]

$$y^2_{RMS} = y^2_{eff} = \frac{1}{T}\int_0^T y^2(t)\cdot dt$$

∴ Note :-

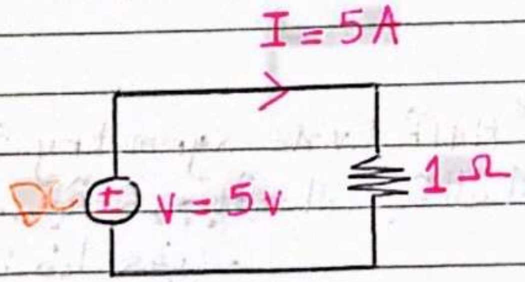
- VRMS Value :-

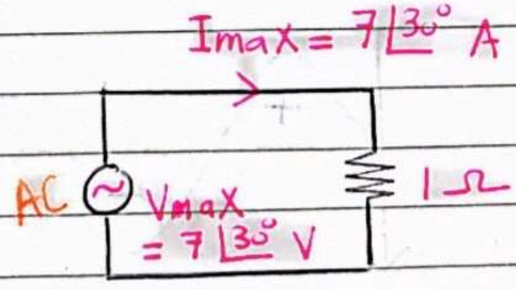
$$V_{RMS} = \frac{1}{T}\int_0^T V^2(t)\cdot dt = \frac{V_{max}}{\sqrt{2}}$$

- IRMS value :-

$$I_{RMS} = \frac{1}{T}\int_0^T I^2(t)\cdot dt = \frac{I_{max}}{\sqrt{2}}$$

so :-



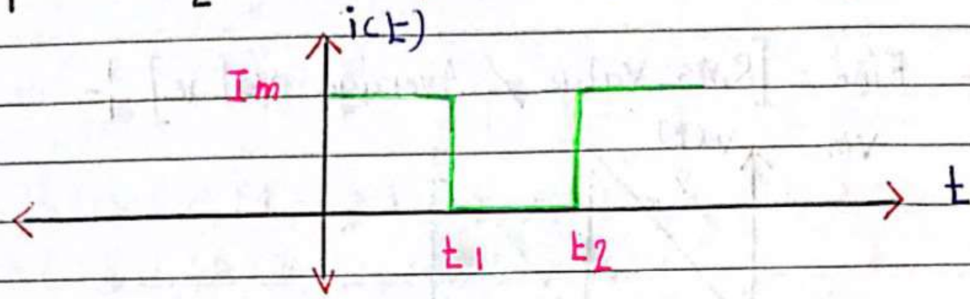


$$P = VI = 5\times 5 = 25 \text{ watt.}$$

$$P = V_{RMS}\times I_{RMS} = \frac{7}{\sqrt{2}}\times\frac{7}{\sqrt{2}} \cong 25 \text{ watt.}$$

=> so the both delivers the same average power to the resistor.

④ :- Find [RMS value / Average value] :-



$$- \; I_{avg} = \frac{1}{T}\int_0^T i(t) \cdot dt$$

$$= \frac{1}{t_2}\int_0^{t_2} I_m \cdot dt$$

$$= \frac{1}{t_2}\left[\int_0^{t_1} I_m \cdot dt + \cancel{\int_{t_1}^{t_2} zero \cdot dt}\right]$$

$$= \frac{1}{t_2} \times I_m \left[t_1 - 0\right]$$

$$= I_m \frac{t_1}{t_2} \quad , \quad \text{if } t_1 = t_2 \, , \; I_{avg} = I_m \, .$$

$$- \; I_{RMS}^2 = \frac{1}{T}\int_0^T i^2(t) \cdot dt$$

$$= \frac{1}{t_2}\int_{t_1}^{t_2} I_m^2 \cdot dt$$

$$= \frac{1}{t_2}\left[\int_0^{t_1} I_m^2 \cdot dt_1 + \cancel{\int_{t_1}^{t_2} zero^2 \cdot dt}\right]$$

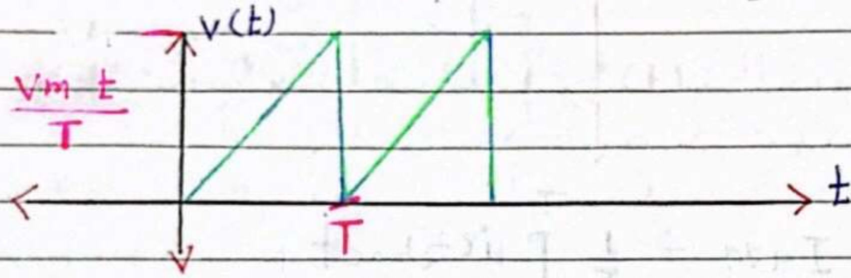
$$= \frac{1}{t_2} \times I_m^2 \left[t_1 - 0\right]$$

$$I_{RMS}^2 = I_m^2 \, \frac{t_1}{t_2}$$

$$I_{RMS} = \sqrt{I_m^2 \frac{t_1}{t_2}}$$

$$I_{RMS} = I_m \sqrt{\frac{t_1}{t_2}}$$

Q :- Find [RMS Value / Average value] :-



- $V_{avg} = \frac{1}{T} \int_0^T v(t) \cdot dt$

$$= \frac{1}{T} \int_0^T \frac{Vm\,t}{T} \cdot dt$$

$$= \frac{1}{T^2} \int_0^T Vm\,t \cdot dt$$

$$= \frac{1}{T^2} \left[\frac{Vm\,t^2}{2}\right]_0^T$$

$$= \frac{1}{T^2} \frac{Vm}{2} [T^2 - 0^2]$$

$$= \frac{Vm}{2}$$

- $V_{RMS}^2 = \frac{1}{T} \int_0^T v^2(t) \cdot dt$

$$= \frac{1}{T} \int_0^T \frac{Vm^2 t^2}{T^2} \cdot dt$$

$$= \frac{1}{T} \left[\frac{Vm^2}{T^2} \frac{t^3}{3}\right]_0^T$$

$$= \frac{Vm^2}{3T^3}\left[t^3\right]_0^T$$

$$= \frac{Vm^2}{3T^3}\left[T^3 - 0^3\right]$$

$$VRMS^2 = \frac{Vm^2}{3}$$

$$VRMS = \frac{Vm}{\sqrt{3}}$$

Q :- Find [VRMS/Vavg] :-

1] $v(t) = 2 + 2\sin wt$

- $Vavg = 2 + Zero = 2V$

- $VRMS = \sqrt{(2)^2 + \left(\frac{2}{\sqrt{2}}\right)^2} = \sqrt{4+2} = \sqrt{6}\,V$

2] $v(t) = 3\cos(\pi t) + 4\sin^2(\pi t)$

$v(t) = 3\cos(\pi t) + 4 \times \frac{1}{2}\left(1 - \cos(2\pi t)\right)$

$v(t) = 3\cos(\pi t) + 2 - 2\cos(2\pi t)$ معطا بقيمة

- $Vavg = Zero + 2 - Zero = 2V$

- $Vavg = \sqrt{\left(\frac{3}{\sqrt{2}}\right)^2 + (2)^2 + \left(\frac{-2}{\sqrt{2}}\right)^2}$

$= 3.24\ V$

∴ Note :-

- $\sin^2\theta = \left[\dfrac{1-\cos 2\theta}{2}\right]$

- $\cos^2\theta = \left[\dfrac{1+\cos 2\theta}{2}\right]$

- حتى اقدر احسب الـ ← [Average value / RMS Value] ،
لازم تكون كل المعادلة [sin or cos] .

3] $v(t) = 10 + 3\cos(10t) + 4\cos(10t - 120^\circ)$

- $V_{avg} = 10 + \text{Zero} + \text{Zero} = 10\ V.$

- $V_{RMS} = ?!$

$V\angle\theta = 10 + 3\angle 0^\circ + 4\angle -120^\circ$

$V\angle\theta = 10 + 3.6\angle -70^\circ$.

$V(t) = 10 + 3.6\cos(10t - 70^\circ)$.

$V_{RMS} = \sqrt{(10)^2 + \left(\dfrac{3.6}{\sqrt{2}}\right)^2} = 10.32V.$

or directly :-

$V_{RMS} = \sqrt{(10)^2 + \left(\dfrac{3}{\sqrt{2}}\right)^2 + \left(\dfrac{4}{\sqrt{2}}\right)^2} = 10.32V.$

4] $v(t) = 6\cos(25t) + 4\sin(25t + 30^\circ)$

- $V_{avg} = \text{Zero}.$

- $V_{RMS} = ?!$

$$v(t) = 6\cos(25t) + 4\cos(25t + 30^\circ - 90^\circ)$$
$$= 6\cos(25t) + 4\cos(25t - 60^\circ)$$
$$V\angle\theta = 6\angle 0^\circ + 4\angle -60^\circ = 8.7\angle -23.4^\circ.$$
$$v(t) = 8.7\cos(25t - 23.4^\circ)$$
$$V_{RMS} = \sqrt{\left(\frac{8.7}{\sqrt{2}}\right)^2} = 6.15\ V.$$

∴ Note :-
to find the RMS value if there are different frequency function :-
$$y_{rms} = \sqrt{y_{rms_1}^2 + y_{rms_2}^2 + \dots}$$
$$\therefore\ y_{rms_1} = \frac{y_{1max}}{\sqrt{2}}\ \text{و}\ y_{rms_2} = \frac{y_{2max}}{\sqrt{2}}\ \text{و} \dots$$

- Instataneous power :- القوة اللحظية
the power at any instant of time.
* In general :- $p = VI$

$$p(t) = v(t) \cdot i(t)\ \text{watt (W)}.$$
[القدرة اللحظية عند زمن معين والتي تعتمد على الزمن]
$$v(t) = V_m \cos(wt + \theta v)\ \text{و}\ i(t) = I_m \cos(wt + \theta i)$$
so :- $p(t) = V_m \cos(wt + \theta v) \times I_m \cos(wt + \theta i)$

so :- $p(t) = \frac{1}{2} V_m I_m \left[\cos(2wt + \theta v + \theta i) + \cos(\theta v - \theta i)\right]$

so :- Avg value for instataneous power :-
$$p_{avg} = \frac{1}{T}\int_0^T p(t)\, dt$$
$$p_{avg} = \frac{1}{2\pi}\int_0^{2\pi} \frac{V_m I_m}{2}\left[\cos(2wt + \theta v + \theta i) + \cos(\theta v - \theta i)\right]$$

لا يعتمد على الزمن $\leftarrow$ $p_{avg} = \frac{V_m I_m}{2} \cos(\theta_v - \theta_i)$ watt ... (1)

V_m :- the maximum value of the voltage.
I_m :- the maximum value of the current.
θ_v :- the voltage angel.
θ_i :- the current angel.

Q :- If :- $v(t) = 120 \cos(377t + 45^\circ)$ V ,
$I(t) = 10 \cos(377t - 10^\circ)$ A ,
Find instataneous and average power.

- $p(t) = \frac{V_m I_m}{2}\left[\cos(2wt + \theta_v + \theta_i) + \cos(\theta_v - \theta_i)\right]$

$= \frac{120 \times 10}{2}\left[\cos(2 \times 377t - 45^\circ) + \cos(45^\circ - 10^\circ)\right]$

$= 600\left[\cos(754t + 35^\circ) + \cos(55^\circ)\right]$

$= \underbrace{344.2}_{p_{avg}} + 600 \cos(754t + 35^\circ)$ W.

- $p_{avg} = \frac{V_m I_m}{2} \cos(\theta_v - \theta_i)$

$= \frac{120 \times 10}{2} \cos(45^\circ - 10^\circ)$

$= 344.2$ W.

Q :- If $Z = [30 - j70]$ Ω , $V = 120 \angle 10^\circ$ V ,
Find the average power.

$I = \frac{V}{Z} = \left[\frac{120 \angle 10^\circ}{30 - j70}\right]$

$$= \frac{120\angle 0^\circ}{76.16\angle -66.8^\circ} = 1.576\angle 66.8^\circ \text{ A}.$$

so :- $$p_{avg} = \frac{v_m I_m}{2} \cos(\theta v - \theta i)$$

$$= \frac{120 \times 1.576}{2} \cos(0 - 66.8^\circ)$$

$$= 37.24 \text{ W}.$$

* Electrical Loads :- [انواع الاحمال]

1] resistive Load :- (R)

[$\theta v = \theta i$] in phase, $\theta v - \theta i = $ Zero,

cos (Zero) = 1.

so :- $$P_R = \frac{1}{2} v_m I_m = \frac{1}{2} \cdot I_m^2 \cdot R = \frac{1}{2} \frac{v_m^2}{R} \quad \dots (1)$$

2] inductive Load :- (L)

[$\theta v \neq \theta i$] out of phase, $\theta v - \theta i = 90^\circ$,

$\cos(90^\circ) =$ Zero.

so :- $$P_L = \frac{1}{2} v_m I_m \cos(90^\circ) = \text{Zero} \quad \dots (2)$$

3] capacitive Load :- (C)

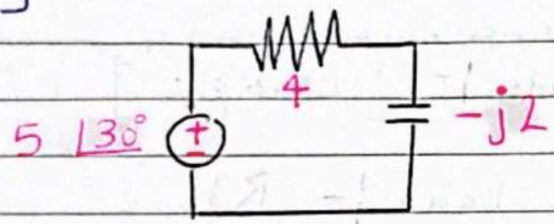
[$\theta v \neq \theta i$] out of phase, $\theta v - \theta i = -90^\circ$,

$\cos(-90^\circ) =$ Zero.

so :- $$P_c = \frac{1}{2} v_m I_m \cos(-90^\circ) = \text{Zero} \quad \dots (3)$$

∴ Note :-
resistive Load absorbs power at all times, while a reactive Load [L / C] absorbs zero avg power.

Ⓠ :- Calculate the average power supplied by the source and average power absorbed by the resistor and capacitor :-



- $I = \frac{V_s}{Z_{eq}} = \frac{5 \angle 30^\circ}{[4 - j2]} = 1.118 \angle 56.57^\circ$ A.

- P_{avg} by the source $= \frac{1}{2} V I \cos(\theta_V - \theta_i)$
$= \frac{1}{2} \times 5 \times 1.118 \cos(30^\circ - 56.57^\circ)$
$= 2.5$ W.

- For the resistor :-
$I_R = I = 1.118 \angle 56.57^\circ$ A.
$V_R = I_R \cdot R = 1.118 \angle 56.57^\circ \times 4$
$= 4.47 \angle 56.57^\circ$ V.
P_{avg} by $R = \frac{1}{2} V_m I_m$
$= \frac{1}{2} \times 1.118 \times 4.47$
$= 2.5$ W.

- For the capacitor :-
P_{avg} by C = zero.

إعداد:-م.سجى البزايعه

Q :- $p(t) = 2 + 10\cos(50t)$, Find [pavg / w] :-

- $p_{avg} = 2 + zero = 2\ W$.

- $w = ?!$
$2wt = 50t$, $w = 25\ [rad/s]$.

In general :- $p(t) = \underbrace{\frac{V_m I_m}{2}\cos(\theta_v - \theta_i)}_{constant} + \underbrace{\frac{V_m I_m}{2}\cos(2wt + \theta_v + \theta_i)}_{Function}$.

Q :- Given that :- $v(t) = 330\cos(10t + 20^\circ)V$, $i(t) = 33\sin(10t + 60^\circ)A$, calculate the instantaneous and average power.

- $i(t) = 33\sin(10t + 60^\circ - 90^\circ)$
$i(t) = 33\sin(10t - 30^\circ)\ A$.

- $p(t) = \frac{1}{2}\left[V_m I_m \cos(\theta_v - \theta_i) + V_m I_m \cos(2wt + \theta_v + \theta_i)\right]$
$= \frac{1}{2}\left[330 \times 33\cos(20^\circ - -30^\circ) + 330 \times 33 \cos(2 \times 10t + 20^\circ + -30^\circ)\right]$
$= \underbrace{3500}_{p_{avg}\ directly} + 5445\cos(20t - 10^\circ)\ W$.

- $p_{avg} = \frac{1}{2}V_m I_m \cos(\theta_v - \theta_i)$
$= \frac{1}{2} \times 330 \times 33 \cos(20^\circ - -30^\circ)$
$= 3500\ W$.

so :- Avg value in RMS for instantaneous power :-

$$P_{RMS} = \sqrt{\frac{1}{T}\int_0^T p(t)^2 \cdot dt}$$

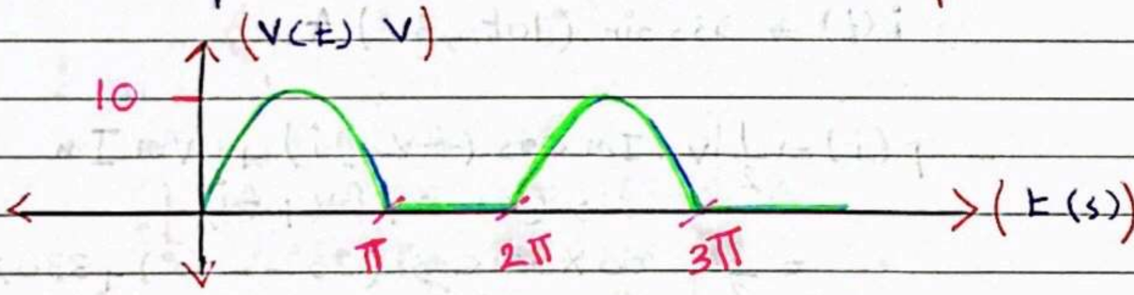
$$P_{RMS} = \sqrt{\frac{1}{2\pi}\int_0^{2\pi} \left[\frac{V_m I_m}{2}\cos(\theta v - \theta i) + \frac{V_m I_m}{2}\cos(2wt + \theta v + \theta i)\right]^2 \cdot dt}$$

$$\underset{(RMS)}{P_{avg}} = V_{RMS}\, I_{RMS} \cos(\theta v - \theta i) \text{ watt} \quad \dots (2)$$

∴ Note :-

P_{avg} = Active power = Real power

Q :- The waveform shown in the figure, is a half-wave rectified sine-wave, find the rms value and the avg power dissipated in a $[10\Omega]$ resistor :-



— $v(t) = \begin{cases} 10 \sin(t), & 0 < t < \pi \\ \text{zero}, & \pi < t < 2\pi \end{cases}$

— $V_{rms} = \sqrt{\frac{1}{T}\int_0^T v(t)^2 \cdot dt}$

$$= \sqrt{\frac{1}{2\pi}\int_0^{\pi} 100\sin^2(t) + \int_{\pi}^{2\pi} (\text{Zero})^2 \cdot dt}$$

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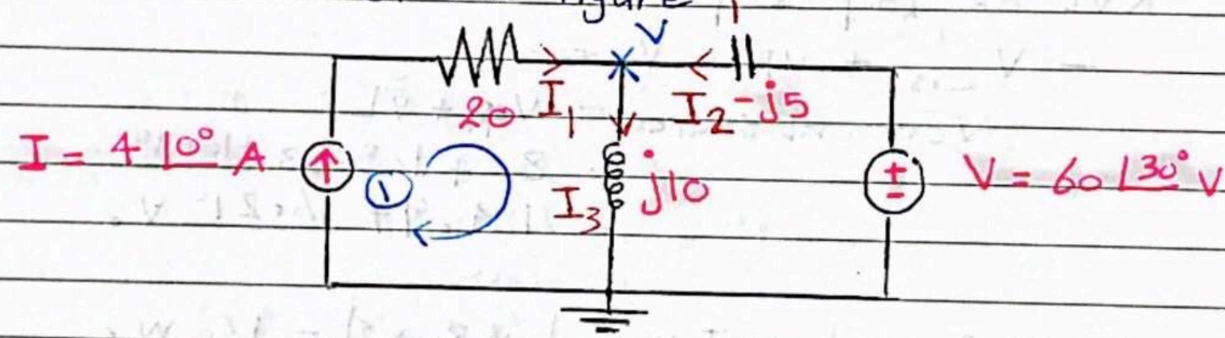
$V_{rms} = 5V$.

$- P_{avg_R} = \frac{1}{2} V_m I_m \cancel{\cos(\theta v - \theta i)} = \frac{V_m}{\sqrt{2}} \frac{I_m}{\sqrt{2}}$

$= V_{rms} I_{rms} = \frac{V_{rms}^2}{R} = \frac{(5)^2}{10} = 2.5 W$.

Q :- Determine the average power generated by each source and the average power absorbed by each passive element in the circuit of the Figure :-



- KCL at the node :-

$I_1 + I_2 = I_3$

$4\angle 0° + \left[\frac{60\angle 30° - V}{-j5}\right] = \frac{V - 0}{j10}$

$\left(4 + \frac{60\angle 30°}{-j5} - \frac{V}{-j5} = \frac{V}{j10}\right) \times 10$

$40 + 120\angle 120° - j2V = -jV$

$V = 105.83\angle 10.89° V$.

$- I_2 = \frac{60\angle 30° - 105.83\angle 10.89°}{-j5}$

$= 10.58\angle -100.89° A$.

- $I_3 = \frac{V}{j10} = \frac{105.83 \angle 10.89^\circ}{j10} = 10.58 \angle -79.1^\circ\ A$.

- $V_R = I_1 \cdot R = 4\angle 0^\circ \times 20 = 80\ V$.

- $V_L = I_3 \cdot Z_L = V = 105.83 \angle 10.89^\circ\ V$.

- $V_c = I_2 \cdot Z_c = 10.58 \angle -100.89^\circ \times -j5$
$= 52.9 \angle 164.11^\circ\ V$.

- KVL at Loop 1 :-
$-V_{c.s} + V_R + V_L = 0$
$V_{current\ source} = V_R + V_L$
$= 80 + 105.83 \angle 10.89^\circ$
$= 184.97 \angle 6.21^\circ\ V$.

- $P_{abs\ R} = \frac{1}{2} V_m I_m = \frac{1}{2} \times 80 \times 4 = 160\ W$.
$P_{abs\ L} = \frac{1}{2} V_m I_m \cos(\theta v - \theta i) = \text{Zero}$.
$P_{abs\ C} = \frac{1}{2} V_m I_m \cos(\theta v - \theta i) = \text{Zero}$.

- P_{gen} [voltage source] $= -\frac{1}{2} V_m I_m \cos(\theta v - \theta i)$
$= \frac{1}{2} \times 60 \times 10.58 \times \cos(30^\circ - -100.84^\circ)$
$= 207.563\ W$.
P_{gen} [current source] $= -\frac{1}{2} V_m I_m \cos(\theta v - \theta i)$
$= \frac{1}{2} \times 184.97 \times 4 \times \cos(6.21^\circ - 0^\circ)$
$= -367.77\ W$.

- حتى نتأكد يجب ان يكون مجموع [power] لكل عناصر الدارة = صفر.
$\sum P = P_R + P_c + P_L + P_{c.s} + P_{v.s}$
$= 160 + 207.563 + -367.77$
$= \text{Zero}$. ###

∴ Note :-

- بالنسبة للـ [sources] الموجودين في الدارة الكهربائية وهما :-
[Voltage source / current source] فهي مصادر منتجة للطاقة
وعند إيجاد [power generated by the source] نضرب القانون بـ [سالب].

- بالنسبة للـ [passive elements] الموجودين في الدارة الكهربائية وهم :-
[inductors / capacitors / Resistors] فهي عناصر مستهلكة
للطاقة وعند إيجاد [power absorbed by the elements] يبقى
القانون كما هو ولا نضرب بـ [سالب].

— Apparent power :- [القدرة الظاهرية] S

$$S = V_{rms} I_{rms} = \frac{V_m I_m}{2} \quad \ldots (VA) \quad (3)$$

∴ Note :-

(VA) ⟶ [Voltage - Ampere]

— power Factor :- [معامل القدرة] pF

$$pF = \cos(\theta v - \theta i) \quad \ldots \text{لا وحدة له} \quad (4)$$

so :- $$p_{avg} = pF \times P_{apparent} = S \times pF \quad \ldots W \quad (5)$$

Ⓠ :- $i(t) = 4\cos(100\pi t + 10°)\,A$ و
$v(t) = 120\cos(100\pi t - 20°)\,V$ و
Find the apperent power and value of
C :-

$$S = V_{RMS} I_{RMS} = \frac{V_m I_m}{2} = \frac{4 \times 12}{2} = 240\ VA.$$

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- c ?!

$X_c = \frac{-1}{wc}$

* to Find X_c :-

$Z = \frac{V \angle \theta v}{I \angle \theta i} = \frac{120 \angle -20°}{4 \angle 10°} = 3 \angle -30°$

$= [25.98 - j15] \ \Omega$.

so :- $Z = \left[R - \frac{j}{wc}\right]$

$X_c = -15$.

so :- $X_c = \frac{-1}{wc}$

$-15 = \frac{-1}{wc}$, $w = 100\pi$ rad/s

$-15 = \frac{-1}{100\pi \times c}$

$c = 212.2 \ MF$.

∴ Note :-

- $pF = 1 \longrightarrow \theta v - \theta i = 0°$, $\cos(\theta v - \theta i) = 1$ [purely resistive Load] .
- $pF = 0 \longrightarrow \theta v - \theta i = +90°$, $\cos(\theta v - \theta i) = 0$ [purely inductive Load] .
- $pF = 0 \longrightarrow \theta v - \theta i = -90°$, $\cos(\theta v - \theta i) = 0$ [purely capacitive Load] .
- $0 < pF < 1 \longrightarrow$ is said to be [Leading or Lagging] .

so :- $0 \leq pF \leq 1$

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∴ Note :-

- Leading and Lagging pF :-

1] Leading pF $\longrightarrow$ [current Leads voltage]

For capacitor $\longrightarrow$ pF (+).

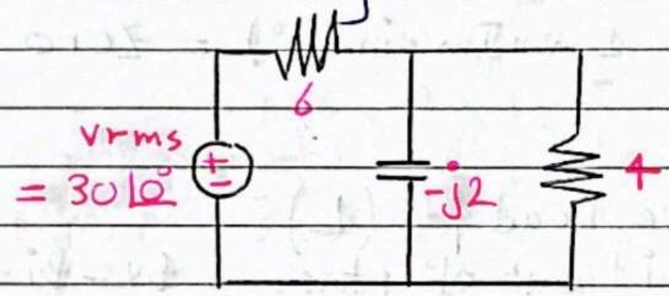
$\theta z = \theta v - \theta i = (-)$, $\cos(\theta z) = (+)$.

2] Lagging pF $\longrightarrow$ [current Lags voltage]

For inductor $\longrightarrow$ pF (+).

$\theta z = \theta v - \theta i = (+)$, $\cos(\theta z) = (+)$.

Q :- Determine the pF for the shown circuit as seen by the source , Calculate the avg power delivered by the source :-



- $Zeq = [4 // -j2] + 6 = \dfrac{4 \times -j2}{4 + -j2} + 6$
$= 7 \angle -13.24° \ \Omega$.

- $pF = \cos(\theta v - \theta i) = \cos(\theta Z) = \cos(-13.24°)$
$= 0.9734$. $[\theta i > \theta v]$ Leading pF

- $pavg = I_{rms} V_{rms} \ pF$

$I_{rms} = \dfrac{V_{rms}}{Z} = \dfrac{30 \angle 0°}{7 \angle -13.24°} = 4.286 \angle 13.24° \ A$.

$pavg = I_{rms} V_{rms} \ pF$
$= 4.286 \times 30 \times \cos(0° - 13.24°)$
$= 125 \ W$.

إعداد:-م.سجى البزايعه

- Reactive power :- Q [القدرة الوهمية]

$$Q = V_{rms} I_{rms} \sin(\theta_v - \theta_i) = \frac{V_m I_m}{2} \sin(\theta_v - \theta_i)$$

VAR ... (4)

* electrical Loads :- [أنواع الأحمال]

1] resistive Load :- (R)

[$\theta_v = \theta_i$] in phase , $\theta_v - \theta_i = \text{Zero}$,
$\sin(\text{Zero}) = \text{Zero}$.

so :- $Q_R = \frac{1}{2} V_m I_m \sin(0°) = \text{Zero}$ ... (1)

2] inductive Load :- (L)

[$\theta_v \neq \theta_i$] out of phase , $\theta_v - \theta_i = 90°$,
$\sin(90°) = 1$.

so :- $Q_L = \frac{1}{2} V_m I_m \sin(90°) = \frac{1}{2} V_m I_m$ ... (2)

3] capacitive Load :- (C)

[$\theta_v \neq \theta_i$] out of phase , $\theta_v - \theta_i = -90°$,
$\sin(-90°) = -1$.

so :- $Q_C = \frac{1}{2} V_m I_m \sin(-90°) = \frac{-1}{2} V_m I_m$ ... (3)

* $Q_L = V_{rms} I_{rms} = \frac{V_{rms}^2}{X_L} = I_{rms}^2 \times X_L$

* $Q_c = -V_{rms} I_{rms} = \frac{-V_{rms}^2}{X_c} = -I_{rms}^2 X_c$

∴ Note :-

- Average power :- تعتمد هذه القدرة على المقاومة فقط ، وهي القدرة المفتحة في المقاومة .
- Reactive power :- تعتمد هذه القدرة على المحث والمكثف ، وهي القدرة المتبادلة بين المصدر وال [C / L] لأنها عناصر تخزين .

- complex power :- $\tilde{S}$

$$\tilde{S} = \frac{1}{2} \tilde{V} \tilde{I}^* = \tilde{V}_{rms} \tilde{I}_{rms}^* = \frac{|V_{rms}|^2}{\tilde{Z}^*}$$
$$= |I_{rms}|^2 \tilde{Z} \quad VA \quad (5)$$

- ال [complex power] هي نفسها ال [Apparent power] ، ولكن ال [complex power] هي عبارة عن قيمة مع زاوية ولكن ال [Apparent power] هي عبارة عن قيمة بلا زاوية .

∴ Note :-

What is the meaning of [complex conjugate *]?

ex :- $R = (4 + j5)\ \Omega$

$R^* = (4 - j5)\ \Omega$

or

$R = 12 \angle +40^\circ\ \Omega$

$R^* = 12 \angle -40^\circ\ \Omega$

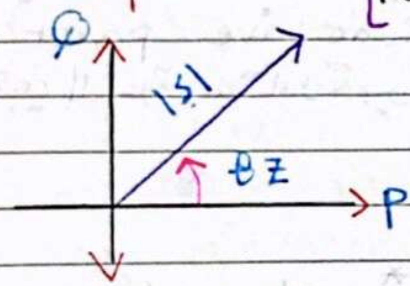
- وهذا يعني عكس إشارة ال [imaginary part] في [rectangular form] أو عكس إشارة ال [phase shift] في ال [phasor form] .

تكملة

- complex power :-

$$\tilde{S} = \underbrace{V_{rms} I_{rms} \cos(\theta_v - \theta_i)}_{P} + j\,\underbrace{V_{rms} I_{rms} \sin(\theta_v - \theta_i)}_{Q}$$

sol:- $\tilde{S} = [P_{avg} \mp jQ] = |S| \angle \pm\theta_z$ ...(6)

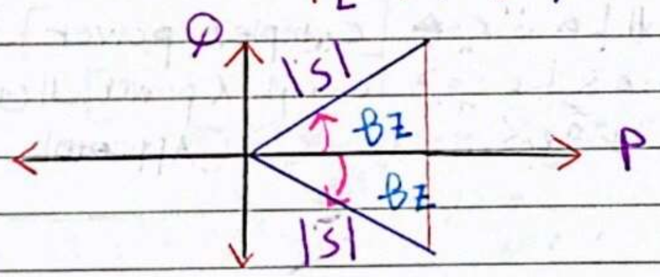


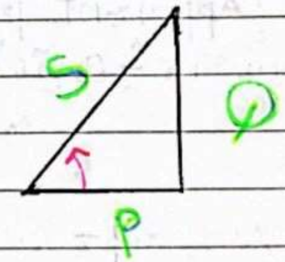
$|S| = \sqrt{P^2 + Q^2}$, magnitude.

$\theta_z = \tan^{-1}\left(\frac{Q}{P}\right)$, phase.

- power triangle :-

يمكن من خلاله إيجاد $[\tilde{S} \,/\, PF \,/\, Q \,/\, S \,/\, P]$:-





Q :- $v(t) = 60 \cos(wt - 10^\circ)$, $i(t) = 1.5 \cos(wt + 50^\circ)$

, Find :- a) complex and apparent powers.

b) real and reactive powers.

c) power factor and load impedence.

a) - $V_{rms} = \frac{60}{\sqrt{2}} \angle -10^\circ$ V.

- $I_{rms} = \frac{1.5}{\sqrt{2}} \angle 50^\circ$ A.

- $\tilde{S} = \tilde{V}_{rms} \tilde{I}_{rms}^{*}$

$$\tilde{S} = \left[\frac{60}{\sqrt{2}} \angle -10^\circ\right] \times \left[\frac{1.5}{\sqrt{2}} \angle -50^\circ\right] = 45 \angle -60^\circ \text{ VA}.$$

– Apparent power $= |\tilde{S}| = S = 45$ VA.

b) – $\tilde{S} = 45 \angle -60^\circ$

$= [22.5 - j\,38.9]$ VA.

– so :- $P_{avg} = 22.5$ W.

$Q = -38.9$ VAR.

c) – $\tilde{S} = 45 \angle -60^\circ$

so :- $\theta_Z = -60^\circ$.

– $pF = \cos(\theta_Z) = \cos(-60^\circ) = 0.5$ Leading.

– Z = Load impedence $= \dfrac{V \angle \theta_V}{I \angle \theta_i} = \dfrac{V_{rms} \angle \theta_V}{I_{rms} \angle \theta_i}$

$$\frac{\frac{60}{\cancel{\sqrt{2}}} \angle -10^\circ}{\frac{1.5}{\cancel{\sqrt{2}}} \angle 50^\circ} = \frac{60 \angle -10^\circ}{1.5 \angle 50^\circ} = 40 \angle -60\ \Omega.$$

[capacitive Load]

Q :- If the impedence is [$Z = 60 + j40\ \Omega$] and the applied Voltage [$v(t) = 320\cos(377t + 10)$ V]

Obtain :- a) pF.

b) Apparent power.

c) Reactive power.

a) – $Z = [60 + j40]$

$= 72.11 \angle 33.69^\circ\ \Omega$.

so :- $pF = \cos(\theta_Z) = \cos(33.69) = 0.832$
Lagging.

b) - $v(t) = 320\cos(377t + 10^\circ)$

$V\angle\theta = 320\angle 10^\circ$ V.

$V_{rms} = \frac{320}{\sqrt{2}}\angle 10^\circ$ V.

- $I = \frac{V}{Z} = \frac{320\angle 10^\circ}{72.11\angle 33.69^\circ}$

$= 4.437\angle -23.69^\circ$ A.

$I_{rms} = \frac{4.437}{\sqrt{2}}\angle -23.96^\circ$ A.

- Apparent power $= S = V_{rms} I_{rms}$

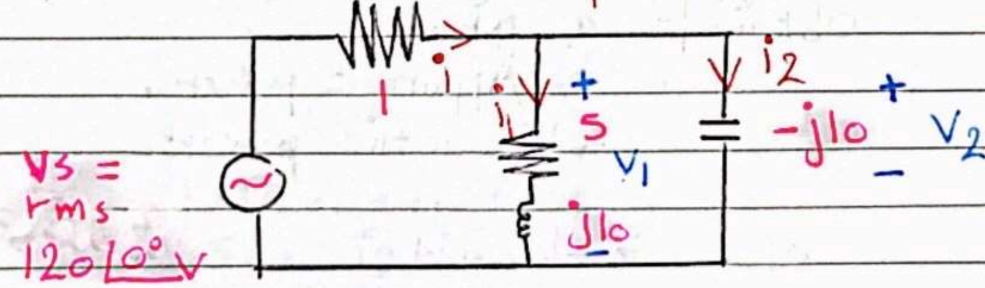
$= \frac{320}{\sqrt{2}} \times \frac{4.437}{\sqrt{2}} = 709.92$ VA.

c) $Q = V_{rms} I_{rms} \sin\theta_Z$

$= \frac{320}{\sqrt{2}} \times \frac{4.437}{\sqrt{2}} \times \sin(33.69)$

$= 393.79$ VAR.

Q :- Find complex power for all elements in the circuit shown :-



- $Z_{eq} = \left[[5+j10] // -j10 \right] + 1$

$= [21 - j10]\ \Omega = 23.26 \angle -25.46^\circ\ \Omega$.

- $i = \frac{V_S}{Z_{eq}} = \frac{120 \angle 0^\circ}{23.26 \angle -25.46^\circ} = 5.16 \angle 25.46^\circ$ A.

- $i_2 = \frac{i \times [5+j10]}{5+\cancel{j10} + \cancel{-j10}} = \frac{5.16 \angle 25.46^\circ \times [5+j10]}{5}$

$= 11.5 \angle 88.9^\circ$ A. current divider

- $i_1 = \frac{i \times -j10}{5+\cancel{j10}-\cancel{j10}} = \frac{5.16 \angle 25.46^\circ \times -j10}{5}$

$= 10.32 \angle -64.54^\circ$ A.

or $\quad i = i_1 + i_2$ و $i_1 = i - i_2$

$= 5.16 \angle 25.46^\circ - 11.5 \angle 88.9^\circ$

$= 10.32 \angle -64.54^\circ$ A.

- $V_2 = -j10 \times i_2 = -j10 \times 11.5 \angle 88.9^\circ$

$= 115 \angle -1.1^\circ$ V.

- $\tilde{S}_{(-j10)} = V_2 I_2^* = 115 \angle -1.1^\circ \times 11.5 \angle -88.9^\circ$

$= -j1322.5$ VA.

- $\tilde{S}_{(1)} = P + jQ$ و $Q_R = \text{zero}$.

$P = I^2 R = (1)(5.16)^2 = 26.625$ W.

so!- $\tilde{S}_{(1)} = 26.625$ VA.

إعداد:-م.سجى البزايعه

— $V_1 = V_2$ [connected in parallel].

— $\tilde{S}_{(5+j10)} = P + jQ$

$P = V I_1 \cos(\theta v - \theta i_1)$

$= 115 \times 10.32 \times \cos(-1.1^\circ + 64.54^\circ)$

$= 532\ W$.

$Q = V I_1 \sin(\theta v - \theta i)$

$= 115 \times 10.32 \times \sin(-1.1^\circ + 64.54^\circ)$

$= 1065\ VAR$.

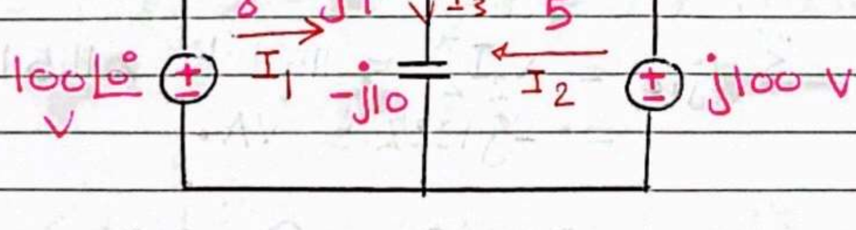
so :- $\tilde{S}_{(5+j10)} = [532 + j1065]\ VA$.

— $\tilde{S}_{(source)} = V I^*$

$= 120 \angle 0^\circ \times 5.16 \angle -25.46^\circ$

$= [559.066 - j266.18]\ VA$.

Q :- Find the complex power generated by each source and the complex power absorbed by each passive elements.



— KCL at the node :-

$I_1 + I_2 = I_3$

$$\left[\frac{100\angle 0^\circ - V}{[6+j4]}\right] + \left[\frac{j100 - V}{5}\right] = \frac{V}{-j10}$$

$$\frac{100}{6+j4} - \frac{V}{6+j4} + \frac{j100}{5} - \frac{V}{5} = \frac{V}{-j10}$$

$$\frac{V}{-j10} + \frac{V}{6+j4} + \frac{V}{5} = \frac{100}{6+j4} + \frac{j100}{5}$$

$$V\left[\frac{1}{-j10} + \frac{1}{6+j4} + \frac{1}{5}\right] = \frac{100}{6+j4} + \frac{j100}{5}$$

$$V\left[\frac{j}{10} + \frac{1}{7.2\angle 33.69^\circ} + \frac{1}{5}\right] = \frac{100}{7.2\angle 33.69^\circ} + \frac{j100}{5}$$

$\times 10$ $$\left(V\left[\frac{j}{10} + 0.1388\angle 33.69^\circ + \frac{1}{5}\right] = 13.88\angle -33.69^\circ + j20\right)$$

$$V = 53.3\angle 42.66^\circ \text{ V}.$$

$$- \; I_1 = \frac{100\angle 0^\circ - V}{6+j4} = \frac{100\angle 0^\circ - 53.3\angle 42.66^\circ}{6+j4}$$
$$= 9.806\angle -64.4^\circ \text{ A}.$$

$$- \; I_2 = \frac{j100 - V}{5} = \frac{j100 - 53.3\angle 42.66^\circ}{6+j4}$$
$$= 14.99\angle 121.6^\circ \text{ A}.$$

$$- \; I_3 = \frac{V}{-j10} = \frac{53.3\angle 42.66^\circ}{-j10} = 5.33\angle 132.66^\circ \text{ A}.$$

$$- \; \underset{(6\Omega)}{\tilde{S}} = P + jQ \; , \; Q_R = \text{zero}.$$

إعداد:-م.سجى البزايعه

$$P_{(6\Omega)} = \frac{1}{2} I_1^2 R = \frac{1}{2} \times (9.806)^2 \times 6$$

$$= 288.47 \text{ W}.$$

so :- $\tilde{S}_{(6\Omega)} = P + jQ = 288.47 \text{ VA}.$

- $\tilde{S}_{(j4)} = P + jQ$, $P = \text{Zero}.$

$$Q_{(j4)} = \frac{1}{2} I_1^2 X_L = \frac{1}{2} \times (9.806)^2 \times j4$$

$$= j192.3 \text{ VAR}.$$

so :- $\tilde{S}_{(j4)} = P + jQ = j192.3 \text{ VA}.$

- $\tilde{S}_{(V.S = 100\angle 0^\circ)} = \frac{1}{2} V I_1^* = \frac{1}{2} \times 100\angle 0^\circ \times (9.806 \angle 64.4^\circ)$

$$= [211.5 + j442.3] \text{ VA}.$$

- $\tilde{S}_{(5\Omega)} = P + jQ$, $QR = \text{Zero}.$

$$P_{(5\Omega)} = \frac{1}{2} I_2^2 R = \frac{1}{2} \times (14.99)^2 \times 5$$

$$= 561.75 \text{ W}.$$

so :- $\tilde{S}_{(5\Omega)} = P + jQ = 561.75 \text{ VA}.$

- $\tilde{S}_{(-j10)} = P + jQ$, $P = \text{Zero}.$

$$Q_{(-j10)} = \frac{1}{2} I_3^2 XL = \frac{1}{2} \times (5.33)^2 \times -j10$$

$$= -142.3 \text{ VAR}.$$

sol:- $\tilde{S}_{(-j10)} = P + jQ = -j142.3$ VA.

- $\tilde{S}_{(v.s = j100)} = \frac{1}{2} V I_2^* = \frac{1}{2} \times 100 \angle 90^\circ \times (14.99 \angle -121.6^\circ)$

$$= [638.37 - j\,392.727] \text{ VA}.$$

sol:- Pavg Total by [passive elements] $= P_{6\Omega} + P_{5\Omega}$

$$= 288.47 + 561.75$$

$$= 850 \text{ W}.$$

- Q Total by [passive elements] $= Q_{(j4)} + Q_{(-j10)}$

$$= j192.3 + -j142.3$$

$$= j50 \text{ VAR}.$$

sol:- $\tilde{S}$ Total absorbed by [passive elements] $= [850 + j50]$ VA.

sol:- $\tilde{S}$ Total generated by [the voltage sources] $= \tilde{S}_{(100)} + \tilde{S}_{(j100)}$

$$= [850 + j50] \text{ VA}.$$

إعداد:-م.سجى البزايعه

∴ Note :-

$$\sum \tilde{S}_{absorbed} = \sum \tilde{S}_{generated}$$

Q :- A Load Z draws 12KVA at a power factor of 0.856 Lagging from a 120 vrms sinusoidal source, calculate :-

a) Average power of the Load.
b) Reactive power of the Load.
c) The peak current.
d) The Load impedence.

a) $P = V_{rms}\, I_{rms}\, pF = S \times pF$
$= 12 \times 10^3 \times 0.856$
$= 10.272\ KW.$

b) $Q = V_{rm}\, I_{rms} \sin(\theta v - \theta i)$
$- \theta z = \cos^{-1}(pF) = \cos^{-1}(0.856)$
$= 31.13°.$

so :- $Q = S \times \sin(\theta v - \theta i)$
$= 12 \times 10^3 \times \sin(31.13°)$
$= 6203.779\ VA.$

c) $\tilde{S} = V_{rms}\, I_{rms}^*$ — Lagging لأنه

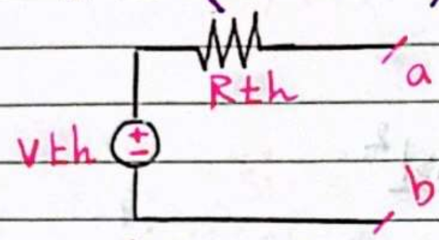
$I_{rms} = \frac{12 \times 10^3}{120} \left(\angle +31.13°\right)^*$
$= 100 \angle -31.13°\ A.$

so :- $I_m = I_{peak} = \sqrt{2} \times I_{rms}$
$= \sqrt{2} \times 100 \angle -31.13°$
$= 141.42 \angle -31.13°\ A.$

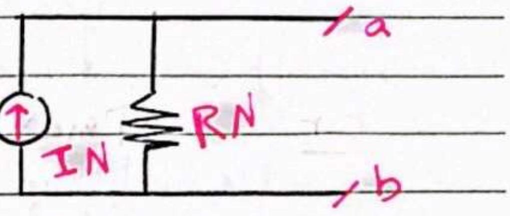
d) $Z = \frac{V}{I} = \frac{120}{100\angle -31.13^\circ} = 1.2\angle 31.13^\circ \ \Omega$.

— Thevenin and Norton :-

* In (circuit "1") :-



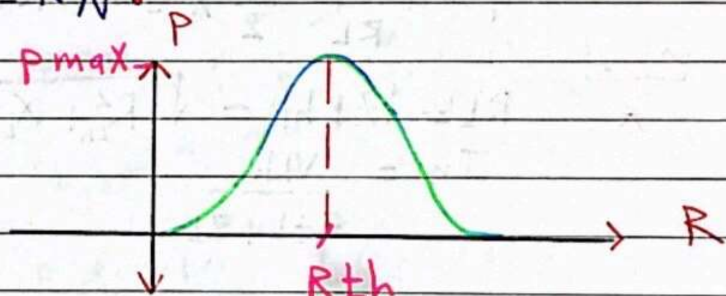
(Thevenin equivalent circuit)



(Norton equivalent circuit)

— $R_{th} = R_N$.

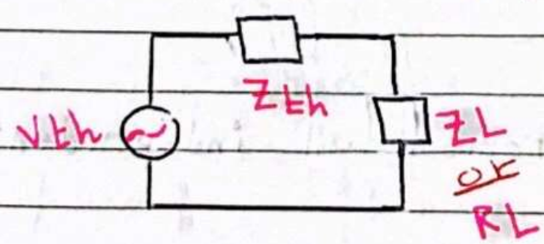
—

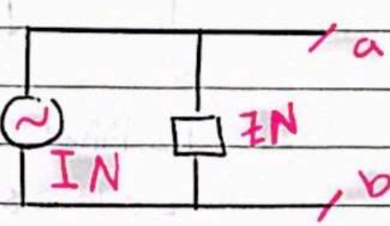


• يمثل هذا المنحنى قيمة (Rth) التي تعطينا [maximum power] •

— $R_L = R_{th} \longrightarrow$ maxim power delivered.

* In (circuit "2") :-





— to get maximum average power :-

$$Z_L = Z_{th}^* = (R_{th} + jX_{th})^* = \boxed{R_{th} - jX_{th}} \quad \ldots (1)$$

- When we obtain the pmax to Load impedence :-

$$P_{max\,Z_L} = \frac{|V_{th}|^2}{8R_{th}} \quad \ldots (2)$$

<u>or</u>

$$P_{max\,Z_L} = \frac{|V_{th\,RMS}|^2}{4R_{th}} \quad \ldots (3)$$

- When we obtain the pmax to Load Resistance :-

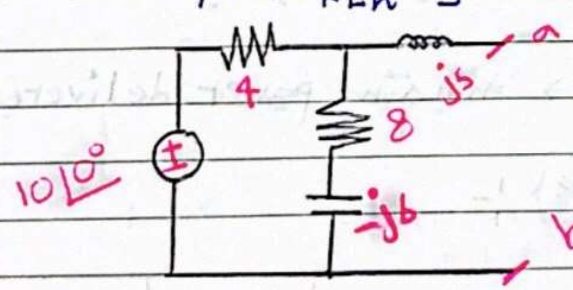
$$P_{max\,R_L} = \frac{1}{2} \times I_m^2 \times R_L \quad \ldots (4)$$

حيث

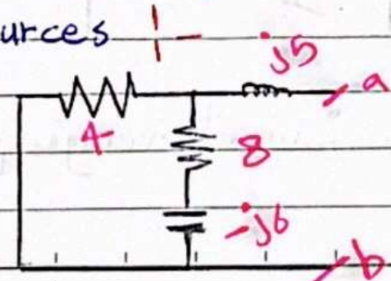
$$R_L = |Z_{th}| = \sqrt{R_{th}^2 + X_{th}^2}$$

$$I_m = \frac{V_{th}}{Z_{th} + Z_L}$$

Q :- Find $P_{max\,R_{th}}$ by using thevenin :-

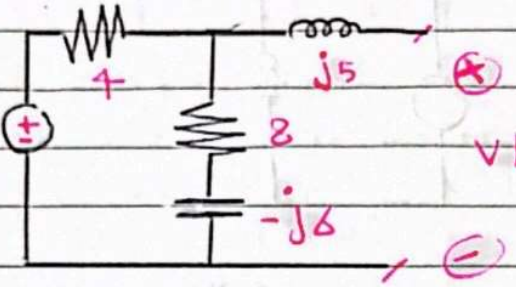


- To find Z_{th}, remove all independent sources :-



- $Z_{th} = j5 + [4 \parallel [8 - j6]]$
$= [2.933 + j\,4.467]\ \Omega.$

- To Find V_{th} , [نعيد جميع المصادر التي حذفت] :-

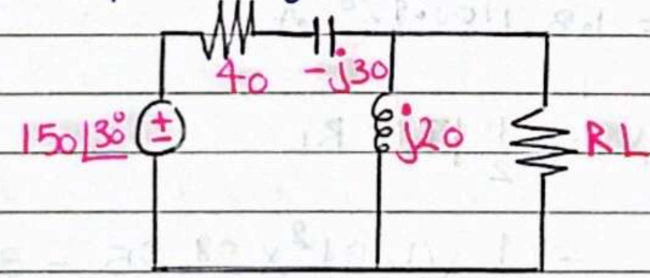


voltage divider – $V_{th} = \dfrac{10\angle 0^\circ \times (8 - j6)}{8 - j6 + 4} = 7.454 \angle -10.3^\circ\ V.$

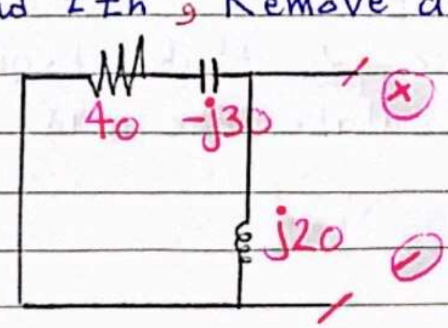
- $Z_L = Z_{th}^* = [2.933 - j4.467]\ \Omega.$

- $P_{max} = \dfrac{|V_{th}|^2}{8 R_{th}} = \dfrac{(7.454)^2}{8 \times 2.933} = 2.368\ W.$

Q :- Find P_{RL} by using thevenin :-



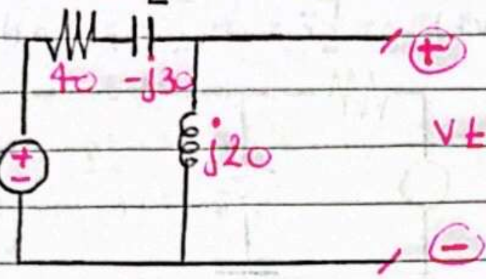
- To Find Z_{th} , Remove all independent sources :-



إعداد:-م.سجى البزايعه

$Z_{th} = [4 - j30] \,//\, j20 = [9.412 + j22.35]\ \Omega$

- To Find V_{th}, [نعيد جميع المصادر التي حذفت] :-



Voltage divider

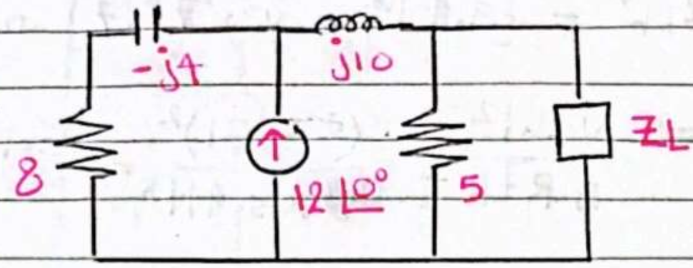
$$V_{th} = \frac{150\angle 30^\circ \times j20}{j20 + 40 + -j30} = 72.76\angle 134^\circ\ V.$$

- $R_L = |Z_{th}| = \sqrt{R_{th}^2 + jX_{th}^2}$
$= \sqrt{(9.412)^2 + (22.35)^2}$
$= 24.25\ \Omega.$

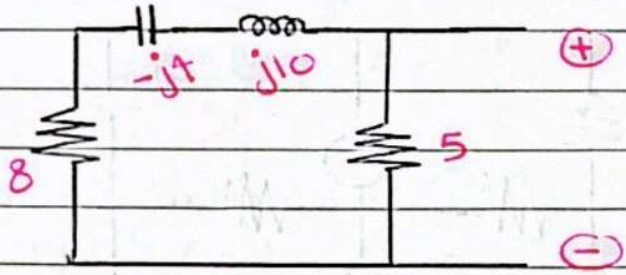
- $$I = \frac{V_{th}}{Z_{th} + R_L} = \frac{72.76\angle 134^\circ}{9.412 + j22.35 + 24.25}$$
$= 1.8\angle 100.42^\circ\ A.$

- $p_{max} = \frac{1}{2}|I|^2 R_L$
$= \frac{1}{2} \times (1.8)^2 \times 24.25 = 39.29\ W.$

Q :- For the cct shown in the figure, find the Load impedence Z_L that absorbs max. avg. power, calculate the max. avg. power :-

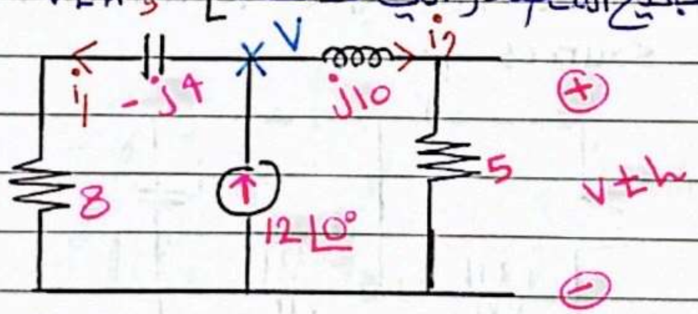


- To Find Z_{th}, remove all independent sources :-



$$Z_{th} = [8 - j4 + j10] \,//\, 5 = [3.414 + j0.7317]\ \Omega .$$

- To find V_{th}, [نعيد جميع المصادر التي حذفت] :-



- To Find V_{th}, KCL at the node :-

$$i_1 + i_2 = 12\angle 0^\circ$$

$$\frac{V}{8-j4} + \frac{V}{5+j10} = 12\angle 0^\circ$$

$$\frac{V}{8} + \frac{V}{-j4} + \frac{V}{5} + \frac{V}{j10} = 12\angle 0^\circ$$

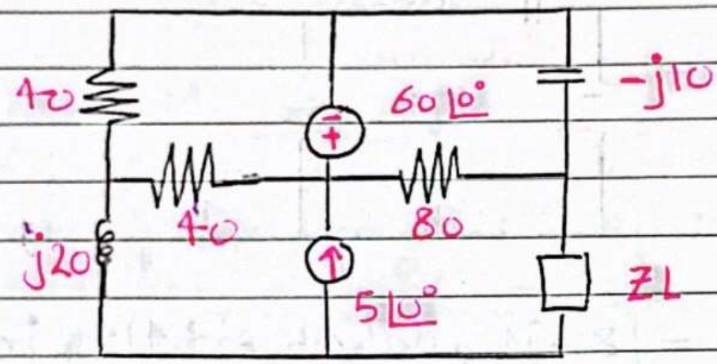
$$V = 83.81\angle 12.09^\circ$$

$$V_{th} = 83.81\angle 12.09^\circ\ V .$$

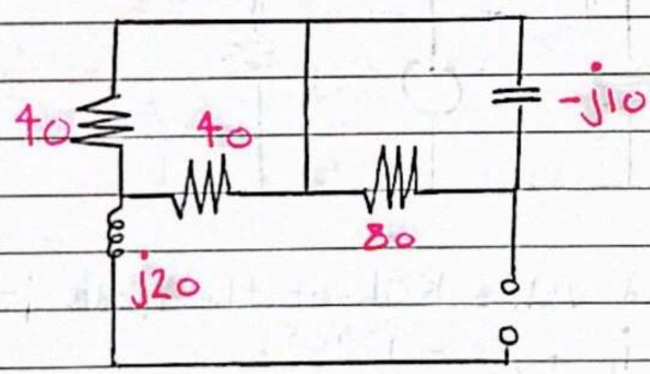
- $Z_L = Z_{th}^* = [3.414 - j0.7317]\ \Omega$.

- $p_{max} = \frac{|V_{th}|^2}{8 R_{th}} = \frac{(83.81)^2}{8 \times 3.414} = 5.143\ W$

Q :- Find Z_L in the circuit and maximum power transfer :-

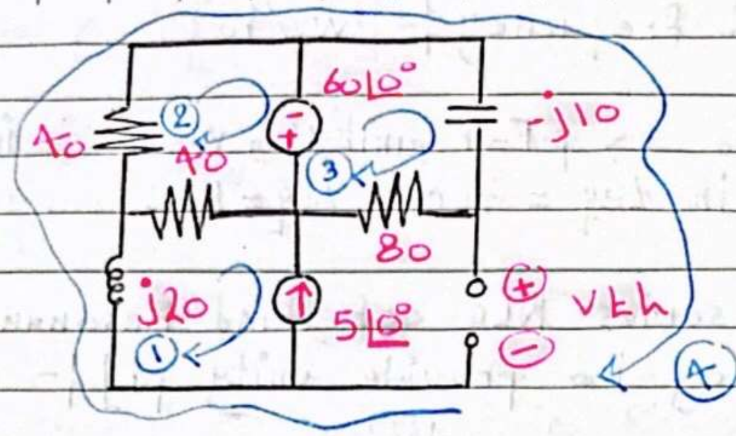


- To find Z_{th}, Remove all independent sources :-



$$Z_{th} = [40 /\!/ 40] + [80 /\!/ -j10] + j20$$
$$= [21.33 + j10.15]\ \Omega.$$

- To find V_{th} و [نعيد جميع المصادر التي حذفت] :-



- $I_1 = -5\angle 0°\ A$.

- KVL at Loop 2 :-

$$40 I_2 - 60\angle 0° + 40 (I_2 - I_1) = 0$$
$$[40 + 40] I_2 - 40 I_1 = 60$$ نعوض I_1
$$80 I_2 + 200 = 60$$
$$I_2 = -1.75\ A.$$

- KVL at Loop 3 :-

$$60\angle 0° + -j10 I_3 + 80 I_3 = 0$$
$$[80 - j10] I_3 = -60$$
$$I_3 = [0.73 - j0.092]\ A.$$

- KVL at Loop 4 , to Find Vth :-

$$j20 I_1 + 40 I_2 + -j10 I_3 + Vth = 0$$
$$Vth = -j20 I_1 - 40 I_2 + j10 I_3$$
نعوض $[I_3 / I_2 / I_1]$
$$Vth = [70.92 + j\,92.7] = 116.7\angle 52.5°\ V.$$

- $ZL = Zth^* = [21.33 - j\,10.15]\ \Omega$.

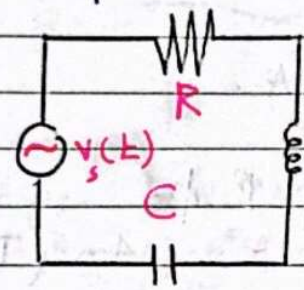
- $$P_{max} = \frac{|Vth|^2}{8\,Rth} = \frac{(116.7)^2}{8 \times 21.33} = 80.1\ W.$$

إعداد:-م.سجى البزايعه

- Resonant frequency :- [W_o/f_o]

at f_o → pF=1 (unity), $W = W_o$, imaginary part in Zeq = Zero, Zeq = R.

Q :- For series RLC cct., Find Resonant Frequency [Frequency to provide unity pF] :-



$$- \quad Z_{eq} = R + jwL + \frac{1}{jwC}$$

$$= R + jwL + \frac{-j}{wC}$$

$$= \underbrace{R}_{X_L} + j \underbrace{\left[wL - \frac{1}{wC}\right]}_{X_C}$$

(Real part) (imaginary part)

At (f_o) → Zeq = R.

so :- $wL - \frac{1}{wC} = \text{Zero}$,

$$wL = \frac{1}{wC}, \quad w = \frac{1}{\sqrt{LC}}.$$

so :- $$f_o = \frac{W_o}{2\pi} = \frac{\frac{1}{\sqrt{LC}}}{2\pi} = \frac{1}{2\pi\sqrt{LC}}.$$

إعداد:-م.سجى البزايعه

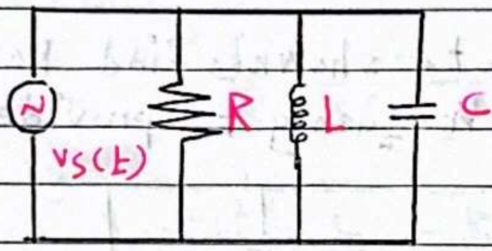
∴ For series (RLC cct.) For (unity pF) :-

$$w = w_o = \frac{1}{\sqrt{LC}} \quad \dots (1)$$

$$f = f_o = \frac{1}{2\pi\sqrt{LC}} \quad \dots (2)$$

---

(4) :- For parallel RLC cct. و Find Resonant Frequency [Frequency to provide unity pF] :-



$$Z_{eq} = R \,//\, jwL \,//\, \frac{1}{jwC}$$

Admittance
مطلوب الـ
Impedence

$$Y_{eq} = \frac{1}{R} + \frac{1}{jwL} + jwC$$

$$= \frac{1}{R} + \frac{-j}{wL} + jwC$$

$$= \underbrace{\frac{1}{R}}_{\text{(Real part)}} + j \underbrace{\left[\frac{-1}{wL} + wC\right]}_{\text{(imaginary part)}}$$

At (f_o) ⟶ $Z_{eq} = R$.

so :- $\frac{-1}{wL} + wC = \text{Zero}$ و

$$wC = \frac{1}{wL} \quad و \quad w = \frac{1}{\sqrt{LC}}.$$

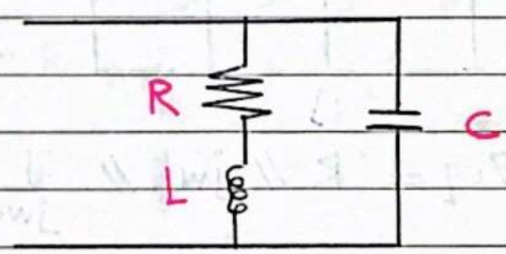
so :- $F_o = \frac{w_o}{2\pi} = \frac{\frac{1}{\sqrt{LC}}}{2\pi} = \frac{1}{2\pi\sqrt{LC}}$.

∴ For parallel (RLC cct.) For (unity pF) :-

$$w = w_o = \frac{1}{\sqrt{LC}} \quad \dots (1)$$

$$f = f_o = \frac{1}{2\pi\sqrt{LC}} \quad \dots (2)$$

Q :- For RLC cct. shown, Find Resonant Frequency [Frequency to provide unity pF] :-



$$Z_{eq} = [R+L] \,//\, C$$

$$= [R + jwL] \,//\, \frac{1}{jwC}$$

Admittance ← مقلوب ال Impedence

$$Y_{eq} = \frac{1}{R+jwL} + jwC \quad \times \frac{R-jwL}{R-jwL}$$

$$= \frac{R-jwL}{R^2+w^2L^2} + jwC$$

$$= \frac{R}{R^2+w^2L^2} + \frac{-jwL}{R^2+w^2L^2} + jwC$$

$$y_{eq} = \frac{R^2}{R^2+w^2L^2} + j\left[wc - \frac{wL}{R^2+w^2L^2}\right]$$

(Real part) (Imaginary part)

At $(F_o) \longrightarrow Z_{eq} = R$.

so :- $wc - \frac{wL}{R^2+w^2L^2} = Zero$,

$wc = \frac{wL}{R^2+w^2L^2}$, $R^2 + w^2L^2 = \frac{L}{c}$,

$w^2L^2 = \frac{L}{c} - R^2$, $W_o = \sqrt{\frac{1}{Lc} - \frac{R^2}{L^2}}$.

so :- $F_o = \frac{W_o}{2\pi} = \frac{1}{2\pi}\sqrt{\frac{1}{Lc} - \frac{R^2}{L^2}}$.

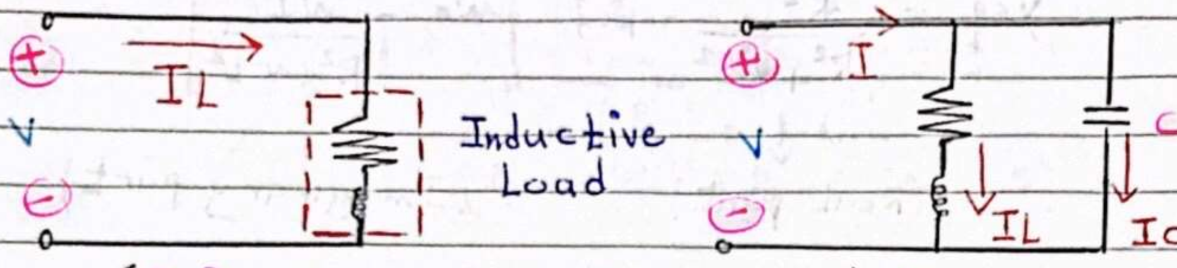
∴ Note :-

إزا كان عند حساب (Zeq) توصيل على التوازي حتى أحولو لجمع نقلب الـ (impedence) وبتتحول لـ (Admittance) .

- power factor correction :- تصحيح معامل القدرة

is the process of increasing (pF) , without without changing the voltage and the current of the original Load .

* تتم عملية تصحيح معامل القدرة عن طريق إضافة مكثفات (C) موصولة على التوازي مع الحمل (Load) وهذا بدوره يقلل الـ (reactive power) ولا تتغير قيمة كل من الجهد والتيار .



"Before" "After"

- كل ما كان معامل القدرة (pF) أقرب من الـ (1) بيكون أفضل وهذا يدل على أن الخسائر أقل وهذا يتبين من :-

$$pF = 1 \longrightarrow \cos^{-1}(1) = Zero.$$

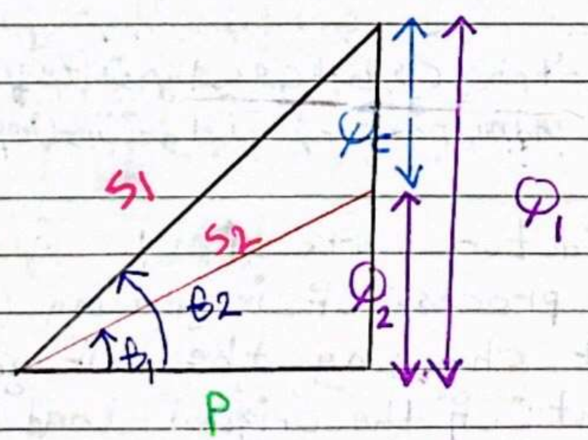
$$Q = \frac{1}{2} vm\, Im \sin\theta = \frac{1}{2} vm\, Im \sin(0) = Zero.$$

$$P = \frac{1}{2} vm\, Im \cos\theta = \frac{1}{2} vm\, Im \cos(0) =$$

$$= \frac{1}{2} vm\, Im.$$

وهذا يعني أنه حصل على كامل القدرة بلا خسائر

- لاشتقاق قانون الـ (capacitor) المضاف لتحسين قيمة PF :-



$$- \quad Q_1 = s_1 \sin\theta_1$$

$$Q_2 = s_2 \sin\theta_2$$

$$- \quad Q_c = Q_1 - Q_2$$

- $Q_c = Q_1 - Q_2$

- $\tan\theta_1 = \frac{Q_1}{P} \longrightarrow Q_1 = P\tan\theta_1$

$\tan\theta_2 = \frac{Q_2}{P} \longrightarrow Q_2 = P\tan\theta_2$

- $Q_c = Q_1 - Q_2 = P(\tan\theta_1 - \tan\theta_2)$

- $Q_c = V_{rms} I_{rms} \sin\theta = I_{rms}^2 \cdot X_c$

$= \frac{V_{rms}^2}{X_c} = WC\, V_{rms}^2$

sol:- $C = \frac{Q_c}{W V_{rms}^2} = \frac{P(\tan\theta_1 - \tan\theta_2)}{W V_{rms}^2}$

Q :- When connected to a 120 vrms, 60 HZ power Line a Load absorbs 4KW at Lagging pF of 0.8, Find the value of capacitance necessery to raise the pF to 0.95 :-

- $C = \frac{Q_c^{?}}{W_{?}\, V_{rms}^2{}_{\checkmark}}$

- $W = 2\pi F = 2\pi \times 60 = 376.99 (rad/s)$.

- $Q_1 = S_1 \sin\theta_1$

$\theta_1 = \cos^{-1}(pF_1) = \cos^{-1}(0.8) = 36.89°$.

$S_1 = \frac{P}{\cos\theta_1} = \frac{4\times10^3}{0.8} = 5\ KVA$.

sol:- $Q_1 = 5\times10^3 \times \sin(36.89°) = 3\ KVAR$.

– $Q_2 = S_2 \sin\theta_2$

$\theta_2 = \cos^{-1}(pF_2) = \cos^{-1}(0.95) = 18.19°$.

$S_2 = \frac{P}{\cos\theta_2} = \frac{4\times10^3}{0.95} = 4210.5\ KVA$.

sol:- $Q_2 = 4210.5 \times 10^3 \times \sin(18.19°) = 1314.4\ VAR$.

– $Q_c = Q_1 - Q_2$

$= 3000 - 1314.4 = 1685.5\ VAR$.

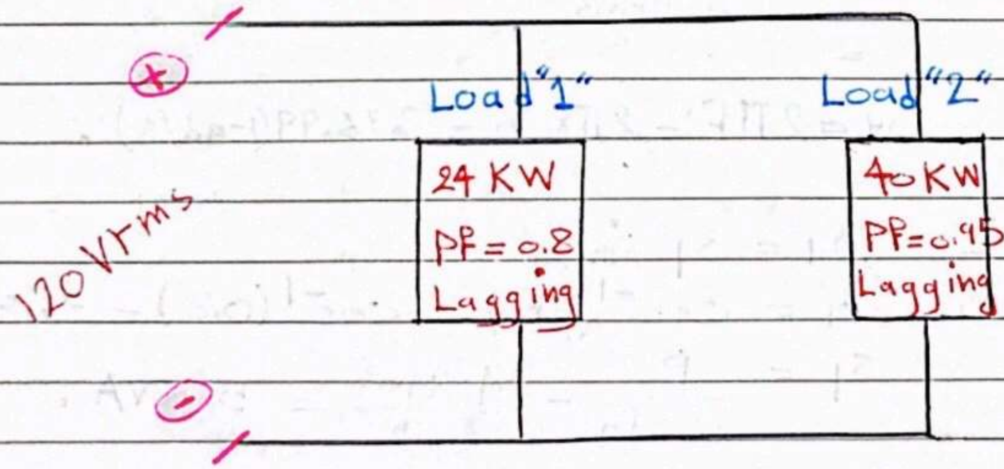
sol:- $C = \frac{Q_c}{w\ Vrms^2} = \frac{1685.5}{376.99 \times (120)^2}$

$= 310.5\ \mu F$.

Q:- A 120 vrms, 60 HZ source supplies two Load connected in parallel, Find:-

a) The power factor of the parallel connection.

b) calculate the value of the capacitor connected in parallel that will raise the power factor to unity.



إعداد:-م.سجى البزايعه

a) - Load 1 :-

$\theta_1 = \cos^{-1}(pf_1) = \cos^{-1}(0.8) = 36.87°$.

$S_1 = \frac{P_1}{pf_1} = \frac{24 \times 10^3}{0.8} = 30\ KVA$.

$Q_1 = S_1 \sin\theta_1 = 30 \times 10^3 \times \sin(36.87°) = 18\ KVAR$.

$S_1 = P_1 + jQ_1 = [24 + j18]\ KVA$.

- Load 2 :-

$\theta_2 = \cos^{-1}(pf_2) = \cos^{-1}(0.95) = 18.19°$.

$S_2 = \frac{P_2}{pf_2} = \frac{40 \times 10^3}{0.95} = 42.105\ KVA$.

$Q_2 = S_2 \sin\theta_2 = 42.105 \times 10^3 \times \sin(18.19°) = 13.143\ KVAR$.

$S_2 = P_2 + jQ_2 = [40 + j13.143]\ KVA$.

- $S_{Total} = S_1 + S_2 = 24 + j18 + 40 + j13.143$

$= [64 + j31.143]\ KVA$.

$\theta = \tan^{-1}\left(\frac{Q}{P}\right)$

$= \tan^{-1}\left(\frac{31.143}{64}\right) = 25.95°$.

$pf_T = \cos\theta = \cos(25.95°) = 0.8992$.

∴ Note :-

لا يجوز ابدًا جمع ال [power Factor for combination] حتى أوجد [pf_2 for $Load_2$ & pf_1 for Load1].

b) - $\theta_1 = 25.95°$.

$\theta_2 = 0°$ / $\cos^{-1}(1) = 0°$ → unity pf.

so :- $C = \frac{P_T[\tan\theta_1 - \tan\theta_2]}{W\ V_{rms}^2}$

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$w = 2\pi f = 2\pi(60) = 120\pi \text{ rad/s}.$

$$C = \frac{64\times10^3 \left[\tan(25.95^\circ) - \tan(0^\circ)\right]}{(120)^2 \times 120\pi} = 5.74\,mF.$$

φ :- Fill the missing information in the table below for each specified load and for the total supplied by the source :-

Load	S VA	P W	φ VAR	θ° degree	p.f	Irms A	Vrms V
A	250	200	-j150	-36.87°	Lead 0.8	1	250
B	300	zero	300	90°	Lag 0	1.2	250
A+B	250	200	j150	36.87°	Lag 0.8	1	250
C	50	40	j30	36.87°	Lag 0.8	1	50
A+B+C	300	240	j180	36.87°	Lag 0.8	1	300

*في رسمة cct بنهاية السؤال [نسيت أرسمها هون :-]

- Load A :-
  - $\theta = \cos^{-1}(pF) = \cos^{-1}(0.8) = 36.87^\circ.$
  - $S = \dfrac{P}{\cos\theta} = \dfrac{200}{0.8} = 250\,VA.$
  - $\varphi = S\sin\theta = 250 \times \sin(-36.87^\circ) = -j150\,VAR.$
  - $I_{rms} = \dfrac{S}{V_{rms}} = \dfrac{250}{250} = 1A.$

- Load B :-
  - $\theta = \cos^{-1}(pF) = \cos^{-1}(0) = 90^\circ.$
  - $P = S\cos\theta = 300 \times 0 = \text{zero}.$
  - $\varphi = S\sin\theta = 300 \times \sin(90^\circ) = 300\,VAR.$

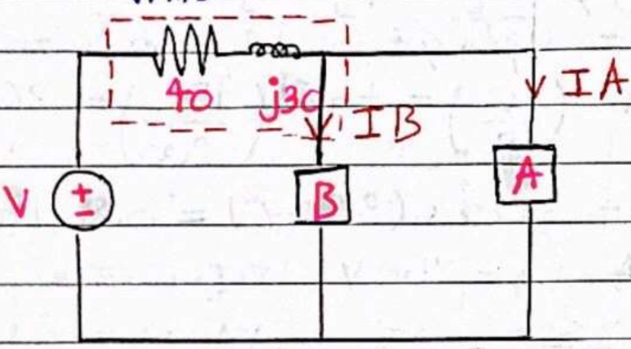
- $V_B = V_A = 250\,V$ [They are in parallel].
- $I_{rms} = \dfrac{S}{V_{rms}} = \dfrac{300}{250} = 1.2\,A$.

- Load A+B :-
  - $P_{A+B} = P_A + P_B = 200 + 0 = 200\,W$.
  - $Q_{A+B} = Q_A + Q_B = -j150 + j300 = j150\ VAR$.
  - $\tilde{S} = P + jQ = [200 + j150]\ VA$.
  - $S = |\tilde{S}| = \sqrt{P^2 + Q^2} = \sqrt{200^2 + 150^2} = 250\ VA$.
  - $\theta = \tan^{-1}\left(\dfrac{Q}{P}\right) = \tan^{-1}\left(\dfrac{150}{200}\right) = 36.87^\circ$.
  - $pF = \cos\theta = \cos(36.87^\circ) = 0.8$ Lagging.
  - $V_{A+B} = V_A = V_B = 250\,V$.
  - $I_{rms} = \dfrac{S}{V_{rms}} = \dfrac{250}{250} = 1A$.

- Load C :-
  - $P = I_{rms}^2 \times R = (1)^2 \times 40 = 40\,W$.
  - $Q = I_{rms}^2 \cdot X_L = (1)^2 \times j30 = j30\ VAR$
  - $\tilde{S} = P + jQ = [40 + j30]\ VA$.
  - $S = |\tilde{S}| = \sqrt{P^2 + Q^2} = \sqrt{40^2 + 30^2} = 50\ VA$.
  - $V_{rms} = \dfrac{S}{I_{rms}} = \dfrac{50}{1} = 50\,V$.
  - $\theta = \tan^{-1}\left(\dfrac{Q}{P}\right) = \tan^{-1}\left(\dfrac{30}{40}\right) = 36.86^\circ$.
  - $pF = \cos\theta = \cos(36.86^\circ) = 0.8$.

- Load A+B+C :-
  - $P_{A+B+C} = P_{AB} + P_C = 200 + 40 = 240\,W$
  - $Q_{A+B+C} = Q_{AB} + Q_C = j150 + j30 = j180\ VAR$.

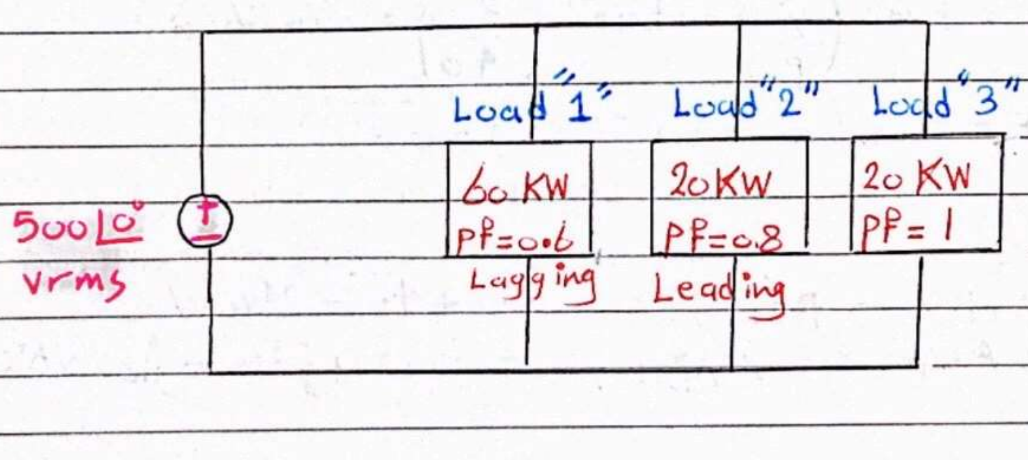
- $\tilde{S} = P + jQ = [240 + j180]$ VA.
- $S = |\tilde{S}| = \sqrt{P^2+Q^2} = \sqrt{240^2+180^2} = 300$ VA.
- $\theta = \tan^{-1}\left(\frac{Q}{P}\right) = \tan^{-1}\left(\frac{180}{240}\right) = 36.86°$.
- $PF = \cos\theta = \cos(36.86°) = 0.8$.
- $V_T = V_{ABC} = V_C + V_{AB} = 250 + 50 = 300V$.
- $I_{rms} = \frac{S}{V_{rms}} = \frac{300}{300} = 1A$.



④ :- Three Loads are connected in parallel across the $500\angle0°$ vrms source shown below :-

a) calculate the power Factor seen by the source assuming that the capacitive reactance Z_C is not connected to the circuit.

b) Find the total compLex supplied by the source if a capacitive reactance of $Z = -j5\,\Omega$ is connected in parallel with the three Loads.



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a) - Load 1 :-

$\theta_1 = \cos^{-1} pf_1 = \cos^{-1}(0.6) = 53.13°$.

$Q_1 = P_1 \tan\theta_1 = 60\times10^3 \times \tan(53.13°) = 80 KVAR$.

$\tilde{S}_1 = P_1 + jQ_1$

$= [60 + j80]$ KVA.

- Load 2 :-

$\theta_2 = \cos^{-1} pf = \cos^{-1}(0.8) = 36.86°$.

$Q_2 = P_2 \tan\theta_2 = 20\times10^3 \times \tan(36.86°) = 15 KVAR$.

$\tilde{S}_2 = P_2 + jQ_2$

$= [20 - j15]$ KVA.

- Load 3 :-

$\theta_3 = \cos^{-1} pf = \cos^{-1}(1) = Zero$.

$Q_3 = P_3 \tan\theta_3 = 20\times10^3 \times \tan(Zero°) = Zero$.

$\tilde{S}_3 = P_3 + jQ_3$

$= 20\times10^3 + Zero = 20$ KVA.

- $\tilde{S}_T = \tilde{S}_1 + \tilde{S}_2 + \tilde{S}_3 = [60 + j80 + 20 - j15 + 20]$ K

$= [100 + j65]$ K $= 119.26 \angle 33.02°$ KVA.

- $pF = \cos\theta = \cos(33.02°) = 0.838$ Lagging.

b) - $I_{rm} = \frac{V_{rms}}{Z_c} = \frac{500\angle0°}{-j50} = j100$ A.

- $\tilde{S}_{(After\ adding\ c)} = V_{rms} I_{rms}^* = 500 \times -j100$

$= -j50$ KVA.

- $\tilde{S}_{Total} = \tilde{S}_1 + \tilde{S}_2 + \tilde{S}_3 + \tilde{S}_c = [100 + j15]$ KVA.

كل هذه الأضواء لن تخبيك

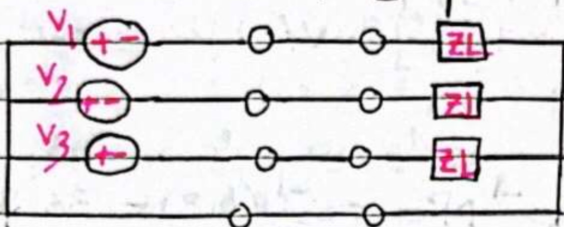
مالم تشرق في أعماقك

شمس

إعداد:- م.سجى البزايعه

CH :- "Three phase circuits" :-

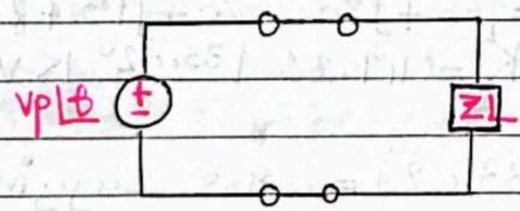
- We will Focus in this chapter on :-



$V_1 = V_P \angle 0^\circ$ V.
$V_2 = V_P \angle 120^\circ$ V.
$V_3 = V_P \angle 240^\circ = V_P \angle -120^\circ$ V.

So :- This demonstrates [Three phase system] with [Four wires system]. ٣ زوايا مختلفة و٤ أسلاك

- Three phase system :- is a combination of three single phase having [the same amplitude but 120° phase shift between each other].



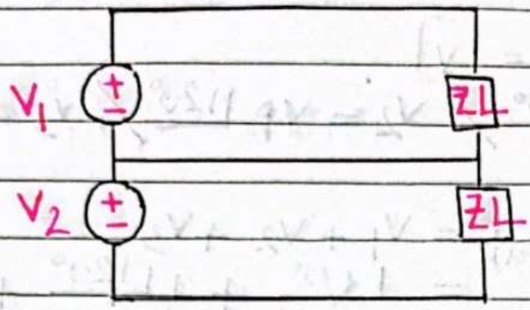
So :- This demonstrates [single phase system] with [two wires system]. زاوية واحدة وسلكان

- Why we use [three phase system] instead of [single phase]?

لأنّ [3∅ system] يتميز باستقرارية وقدرة كبيرة وكما انه يحظى بكفاءة ممتازة.

∴ Note :-

Why the system shown below called [single phase system] ?



$V_1 = V_P \angle 0^\circ \; V.$

$V_2 = V_P \angle 0^\circ \; V.$

- لأنه لا يوجد [phase shift]، حيث أن هنالك زاوية واحدة فسمي هنا النظام [single phase].

- Three phase system :-
  * Balanced three phase system.
  * unbalanced three phase system.

so :- we will Focus on [balanced three phase system] in this chapter.

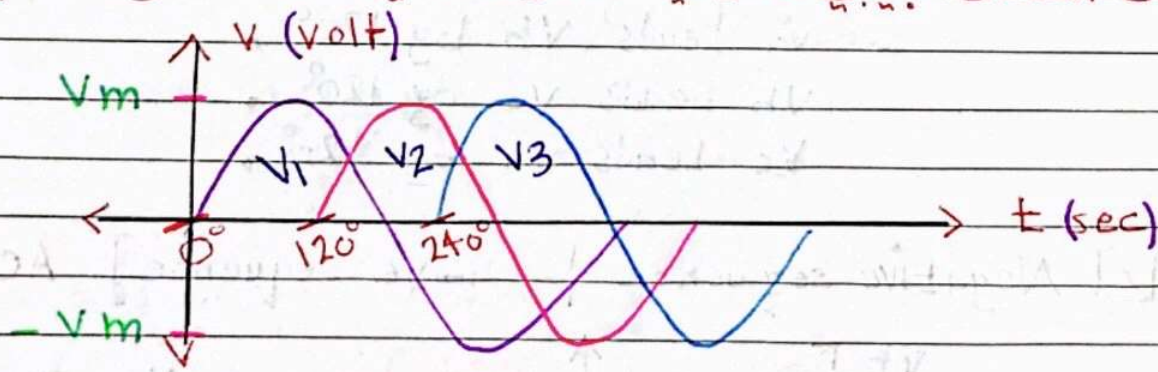
① :- IF there are :-

$V_1 = V_P \angle 0^\circ \; V.$

$V_2 = V_P \angle 120^\circ \; V.$

$V_3 = V_P \angle 240^\circ = V_P \angle -120^\circ \; V.$

فإنّ المنحنى الجيبي للفولتية المتولدة في حالة الاتزان كما يلي :-



∴ Note :-

في النظام المتزن يجب أن يكون المجموع الكلي للجهد يساوي صفر :-

Assume $[V_p = 1V]$

$V_1 = V_p \angle 0^\circ$ / $V_2 = V_p \angle 120^\circ$ / $V_3 = V_p \angle 240^\circ$.

So :- $V_{total} = V_1 + V_2 + V_3$

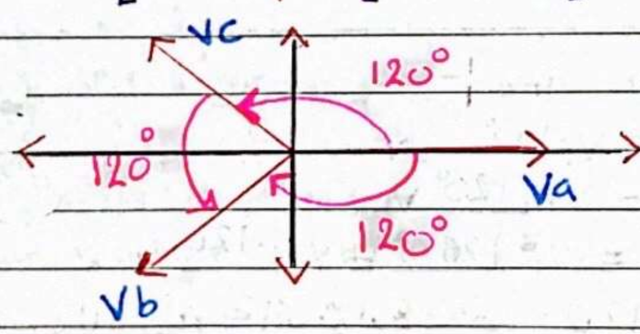
$= 1\angle 0^\circ + 1\angle 120^\circ + 1\angle 240^\circ$

by using calculator $=$ zero

- في [Three phase system] يتم توصيل [phases] حسب تسلسل معين من هذين التسلسلين :-

- Type of sequences :-

$\boxed{1}$ positive sequence :- [+ve sequence] ABC



$V_a = V_m \angle 0^\circ$

$V_b = V_m \angle -120^\circ$

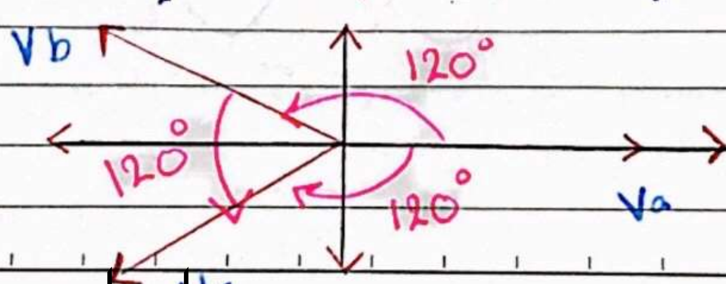
$V_c = V_m \angle 120^\circ$

- Va Leads Vb by 120°.

Vb Leads Vc by 120°.

Vc Leads Va by 120°.

$\boxed{2}$ Negative sequence :- [-ve sequence] ACB



$V_a = V_m \angle 0^\circ$

$V_b = V_m \angle 120^\circ$

$V_c = V_m \angle -120^\circ$

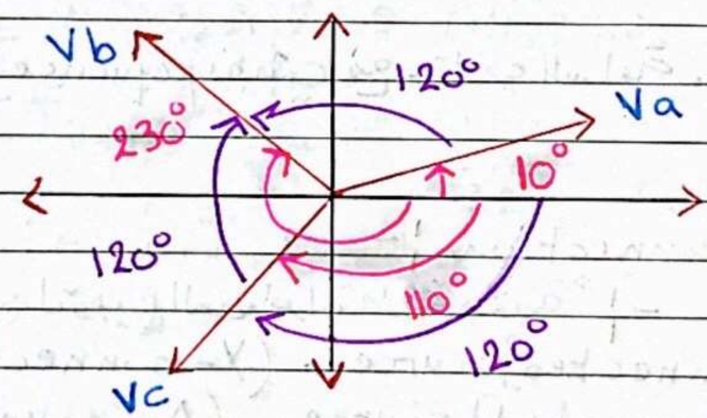
Vc

- Va Leads Vc by 120°.
Vc Leads Vb by 120°.
Vb Leads Va by 120°.

Q:- Determine the phase sequence of the set of voltage:-

$V_a = 200\cos(\omega t + 10°)\ V$.
$V_b = 200\cos(\omega t - 230°)\ V$.
$V_c = 200\cos(\omega t - 110°)\ V$.

- $V_a = 200\angle 10°\ V$. → [reference]
$V_b = 200\angle -230°\ V$.
$V_c = 200\angle -110°\ V$.



so:- it is a negative sequence.
- Va Leads Vc by 120°.
Vc Leads Vb by 120°.
Vb Leads Va by 120°.

Q:- Given that:- $V_b = 110\angle 30°$, Find Va and Vb,
Assume a positive sequence [+ve]:-

- Va Leads Vb by 120°.
Vb Leads Va by 120°.

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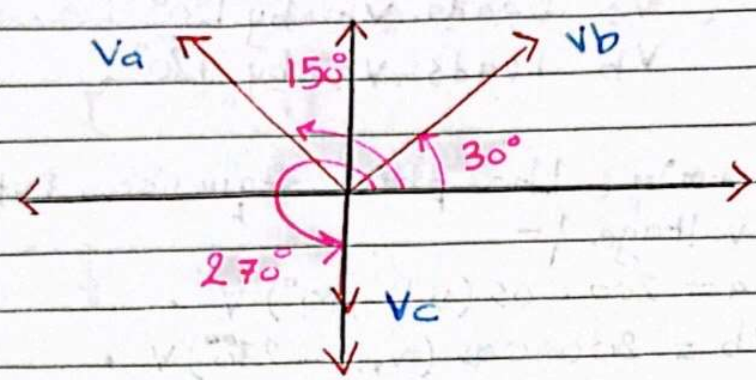
Vc Leads Va by 120°.

Sol:-



$$V_a = 110\angle 150^\circ\,V.$$
$$V_b = 110\angle 30^\circ\,V.$$
$$V_c = 110\angle 270^\circ\,V.$$

+120°
+240°

∴ Note:-

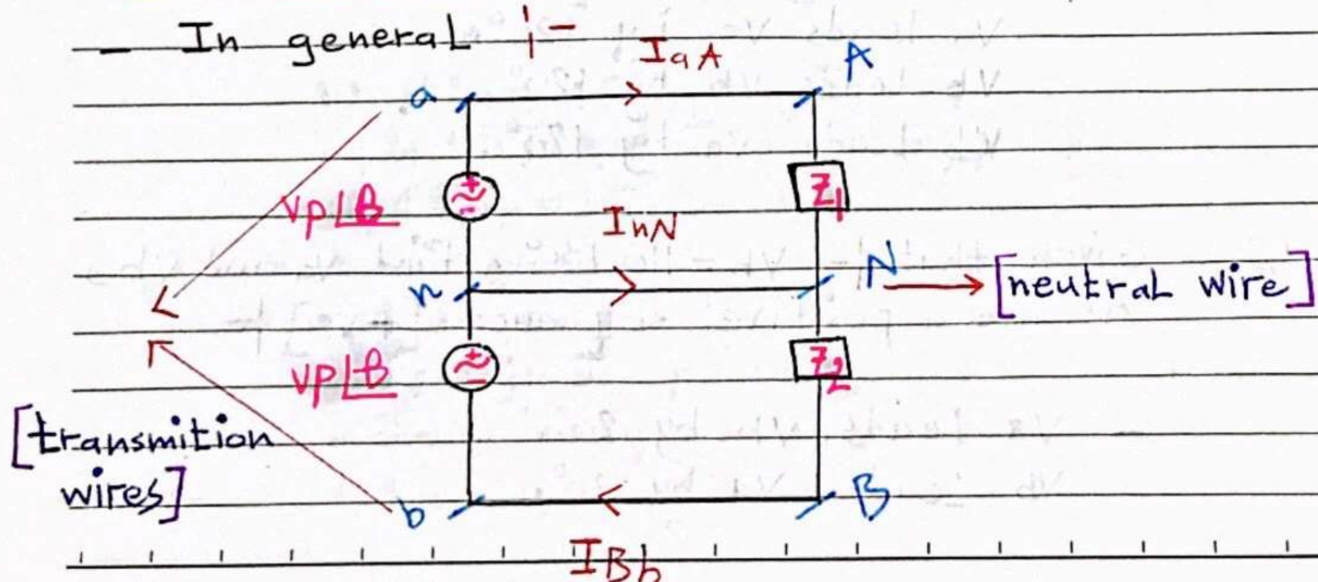
عند تسمية الـ [sequence] نمشي مع عقارب الساعة.

- Types of connection:-

هنالك طريقتين لتوصيل المصادر الثلاثة سوية:-

* [Wye - connected] source. (Y-connected)
* [Delta - connected] source. (Δ - connected)

- In general:-



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∴ Note :-

- small letters [a/b] → [sources توضع بالجزء الموجود في].
- capital letters [A/B] → [Loads توضع بالجزء الموجود في].

so :- $V_{an} = V_p \angle\theta$

$V_{nb} = V_p \angle\theta$

$V_{ab} = V_{an} + V_{nb} = V_p \angle\theta + V_p \angle\theta = 2V_p \angle\theta$

$V_{na} = -V_p \angle\theta$

$V_{bn} = -V_p \angle\theta$

- $V_{AN} = V_{an} = V_p \angle\theta$ [parallel]

$V_{NB} = V_{nb} = V_p \angle\theta$ [parallel]

- $I_{aA} = \dfrac{V_{an}}{Z_1} = \dfrac{V_p \angle\theta}{Z_1}$

$I_{Bb} = \dfrac{V_{nb}}{Z_2} = \dfrac{V_p \angle\theta}{Z_2}$

$I_{nN} = I_{Bb} - I_{aA}$ [by KCL]

∴ Note :-

balanced system → When all Loads in the circuit are [equal]. → $I_{nN} = \text{zero}$.

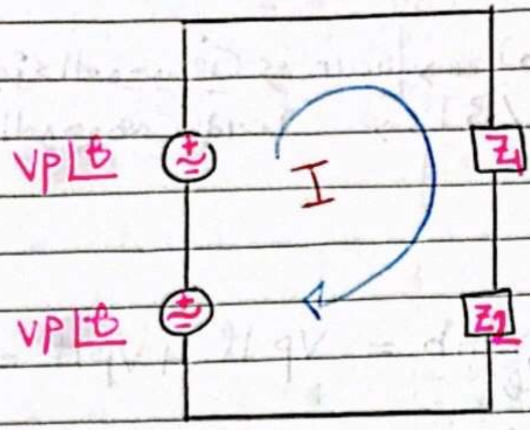
- here is balanced system because :-

[$Z_1 = Z_2$]

so :- $I_{nN} = \text{zero}$.

$I_{Bb} = I_{aA}$.

so :- The circuit will be like this :-

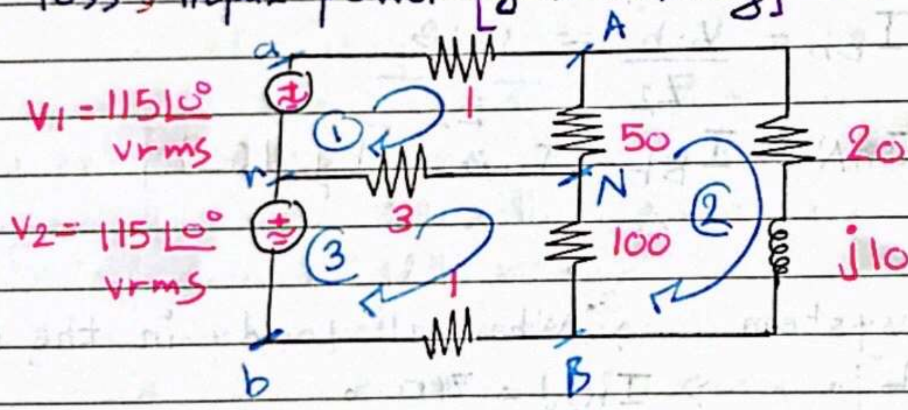


$[Z_1 = Z_2 = Z]$

– by KVL :-

$$I = \frac{\cancel{2}V_p\angle\theta}{\cancel{2}Z} = \frac{V_p\angle\theta}{Z}$$

Q :- Find total power delivered to Loads, power loss, input power [generating] and efficiency :-



– KVL at Loop 1 :-

$$-115\angle 0^\circ + 1 I_1 + 50[I_1 - I_2] + 3[I_1 - I_3] = \text{Zero}$$

$$I_1 + 50 I_1 + 3 I_1 + -50 I_2 - 3 I_3 = 115$$

$$54 I_1 - 50 I_2 - 3 I_3 = 115 \quad \dots (1)$$

– KVL at Loop 2 :-

$$20 I_2 + j10 I_2 + 100[I_2 - I_3] + 50[I_2 - I_1] = \text{Zero}$$

$$20 I_2 + j10 I_2 + 100 I_2 + 50 I_2 + 100 I_3 - 50 I_1 = \text{Zero}$$

$$[170 + j10] I_2 + 100 I_3 + -50 I_1 = \text{Zero} \quad \dots (2)$$

- KVL at loop 3 :-

$$-115\angle 0^\circ + 3[I_3 - I_1] + 100[I_3 - I_2] + 1 I_3 = \text{Zero}$$

$$3I_3 + 100 I_3 + I_3 - 3I_1 - 100 I_2 = 115$$

$$104 I_3 - 3I_1 - 100 I_2 = 115 \quad \dots \quad (3)$$

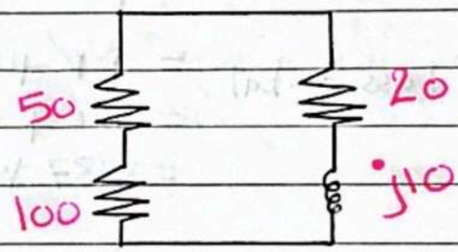
so :- $I_1 = 11.24 \angle -19.83^\circ$ A.

$I_2 = 9.389 \angle -24.47^\circ$ A.

$I_3 = 10.37 \angle -21.8^\circ$ A.

- power delivered to Loads :- [avg power]

هدول هم ال[Loads]



$$P_{50} = I^2 R = [I_1 - I_2]^2 \times 50 = 206 \text{ W}.$$

$$P_{100} = I^2 R = [I_3 - I_2]^2 \times 100 = 117 \text{ W}.$$

$$P_{20} = I^2 R = I_2^2 \times 20 = 1763 \text{ W}.$$

$$P_{j10} = \text{Zero} \longrightarrow [\text{Inductor}]$$

so :- $P_{total} = P_{50} + P_{100} + P_{20} + P_{j10}$

$= 206 + 117 + 1763$

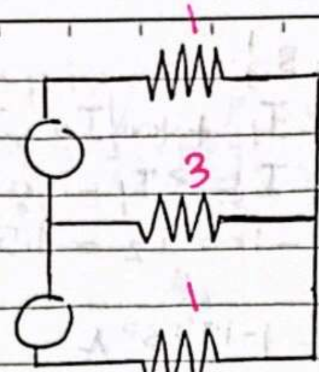
$= 2086$ W.

∴ Note :-

عندما لا يحدد بالسؤال نوع ال[power] المطلوب إيجادها ، نقوم بحساب قيمة ال[Average power].

- power Loss :-

هي ال[power] التي سوف تخسع بال[wires] قبل أن تصل ال[Loads].



$$P_1 = I^2R = I_1^2 \times 1 = 126\,W.$$
$$P_3 = I^2R = [I_1 - I_3]^2 \times 3 = 108\,W.$$
$$P_1 = I^2R = I_3^2 \times 1 = 3\,W.$$

So :- $P_{Loss\ total} = P_1 + P_3 + P_1$
$= 126 + 108 + 3$
$= 237\,W.$

— Input power :-

طريقة 1- $P_{V.S_1} = V_{1\,rms}\, I_{rms_1} \cos(\theta v - \theta i)$
$= 115 \times 11.24 \times \cos(0^\circ - -19.83^\circ)$
$= 1216\,W.$

$P_{V.S\,2} = V_{2\,rms}\, I_{rms\,3} \cos(\theta v - \theta i)$
$= 115 \times 10.37 \cos(0^\circ - -21.8^\circ)$
$= 1107\,W.$

So :- $P_{input} = P_{V.S_1} + P_{V.S\,2}$
$= 1216 + 1107 = 2323\,W.$

طريقة 2 — $P_{input} = P_{delivered\ total} + P_{Loss\ total}$
$= 2086 + 237$
$= 2323\,W.$

∴ Note :-

$$efficiency = \eta = \frac{pout}{pin} \times 100\% \rightarrow [\text{الكفاءة}].$$

- efficiency :-

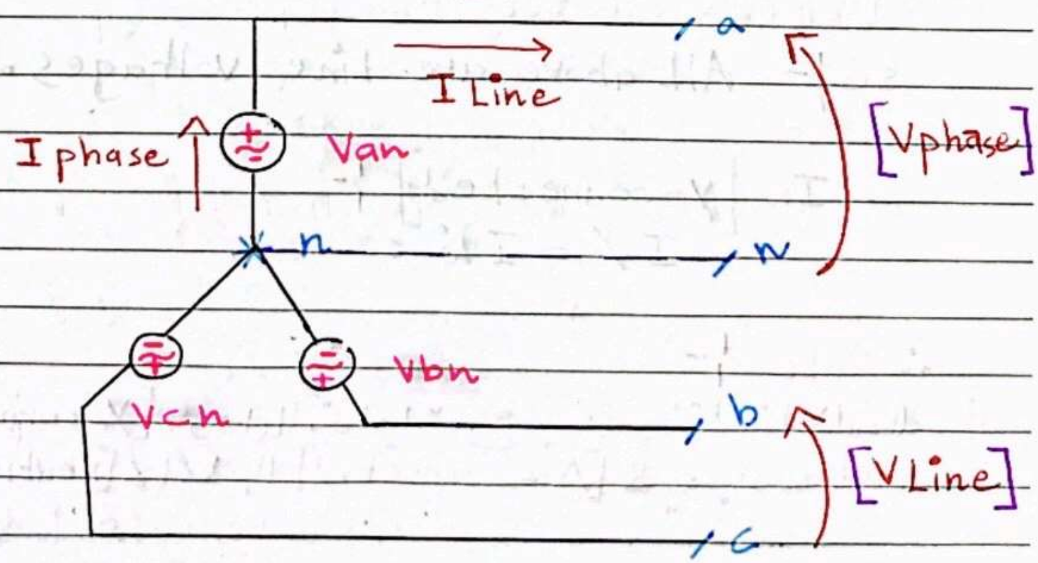
$$efficiency = \eta = \frac{pout}{pin} \times 100\%$$

$$= \frac{p \text{ delivered to Loads}}{pout + pLoss} \times 100\%$$

$$= \frac{2086}{2323} \times 100\% = 87.8\%.$$

لازم تكون الـ[circuit] مصممة بحيث تعطي كفاءة عالية.

I [wye - connected source] :-



∴ Note :-

- Vphase [VØ] → هو الجهد بين أي نقطة موصولة مع الجهد [neutral] الـ.

- $V_{an} = V_p \angle 0^\circ$ V.
$V_{bn} = V_p \angle -120^\circ$ V. For [+ve sequence]
$V_{cn} = V_p \angle 120^\circ$ V.

so :- All above are phase voltages.

∴ Note :-
- V Line [VL] → هو الجهد بين اي نقطتين بوصلتيّ مع مصدر كلاً منها على حدا.

- In [y-connected] :-
$$V_{Line} = \sqrt{3}\, V_\phi \angle 30^\circ \quad \ldots (1)$$
so :- $$V_\phi = \frac{V_{Line} \angle -30^\circ}{\sqrt{3}} \quad \ldots (2)$$

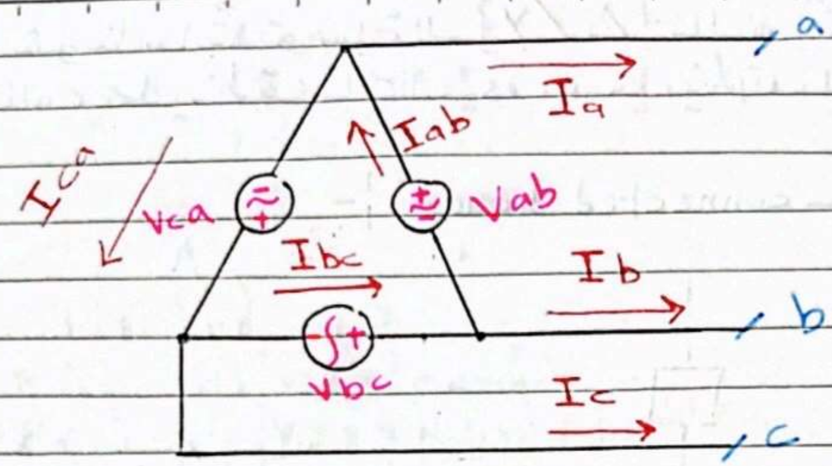
- $V_{ab} = \sqrt{3}\, V_{an} \angle 0^\circ+30^\circ = \sqrt{3}\, V_p \angle 30^\circ$ V.
$V_{bc} = \sqrt{3}\, V_{bn} \angle -120^\circ+30^\circ = \sqrt{3}\, V_p \angle -90^\circ$ V.
$V_{ca} = \sqrt{3}\, V_{cn} \angle 120^\circ+30^\circ = \sqrt{3}\, V_p \angle 150^\circ$ V.

so :- All above are Line voltages.

- In [y-connected] :-
$$I_\phi = I_{Line} \quad \ldots (3)$$

∴ Note :-
في [y-connected] نوصل النهايات مع بعض ونقطة الالتقاء يطلع منها [neutral] ، اما بال [Δ-connected] لا يوجد neutral.

[2] [Delta - connected source] :-



- $V_{ab} = V_a$ V.
  $V_{bc} = V_b$ V.
  $V_{ca} = V_c$ V.

- In [Δ-connected] :-
  $V\phi = V_{Line}$ ... (1)

- $I_{ab} = I_p \angle 0^\circ$ A.
  $I_{bc} = I_p \angle -120^\circ$ A. For [+ve sequence]
  $I_{ca} = I_p \angle 120^\circ$ A.

so :- All above are phase currents.

- In [Δ-connected] :-
  $I_{Line} = \sqrt{3}\, I\phi \angle -30^\circ$ ... (2)
  $I\phi = \dfrac{I_{Line} \angle 30^\circ}{\sqrt{3}}$ ... (3)

- $I_a = \sqrt{3}\, I_{ab} \angle 0^\circ - 30^\circ = \sqrt{3}\, I_p \angle -30^\circ$ A.
  $I_b = \sqrt{3}\, I_{bc} \angle -120^\circ - 30^\circ = \sqrt{3}\, I_p \angle -150^\circ$ A.
  $I_c = \sqrt{3}\, I_{ca} \angle 120^\circ - 30^\circ = \sqrt{3}\, I_p \angle 90^\circ$ A.

so :- All above are Line currents.

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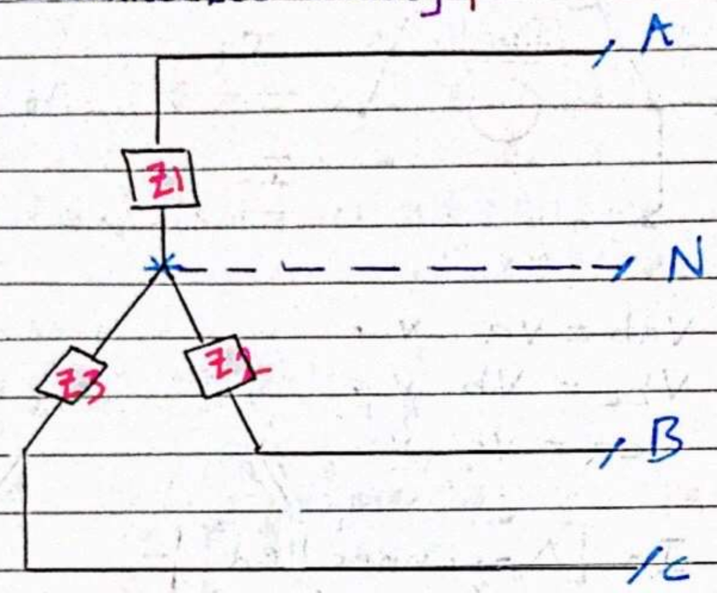
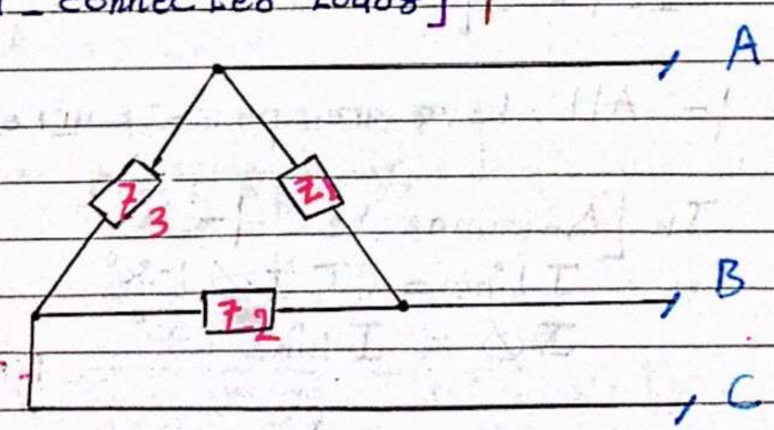
- إحنا شرحنا سابقاً توصيلة الـ [Δ / Y] بالنسبة للـ [sources]
وبالتالي ما ينطبق على الـ [sources] ينطبق على الـ [Loads].

1 [Wye _ connected Loads] :-



وبما أنّ النظام [Balanced] فإنّ :-
$$Z_1 = Z_2 = Z_3 = Z_Y$$

2 [Delta _ connected Loads] :-



وبما أنّ النظام [Balanced] فإنّ :-
$$Z_1 = Z_2 = Z_3 = Z_\Delta$$

- حسابات الجهود والتيارات ما ينطبق على الـ [sources] ينطبق على الـ [Loads] وفي كلا التوصيلين.

- حتى أحول بين $[Y \rightleftarrows \Delta]$:-

$$Z\Delta = 3\,ZY \;...\; (1)$$

$$ZY = \frac{1}{3}\,Z\Delta \;...\; (2)$$

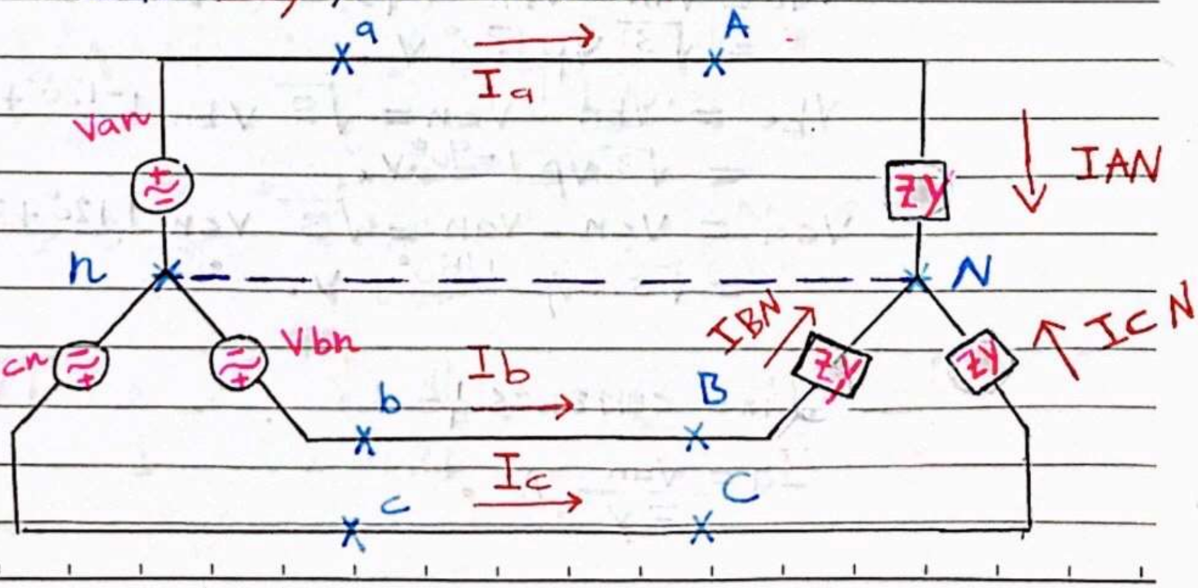
- There are four methods of connection between Sources and Loads :-
  1- Balanced [Y - Y] connection.
  2- Balanced [Y - Δ] connection.
  3- Balanced [Δ - Δ] connection.
  4- Balanced [Δ - Y] connection.

∴ Note :-

- الحل دائمًا بكون على الـ[+ve sequence] إلا إذا ذكر بالسؤال إنّه [-ve sequence].
- جميع الدوائر الكهربائية التي نتعامل معها تكون ← [Balanced].
- في الأربع توصيلات المذكورة أعلاه الرمز الأول يدل على توصيلة الـ[source] والرمز الثاني يدل على توصيلة الـ[Load].

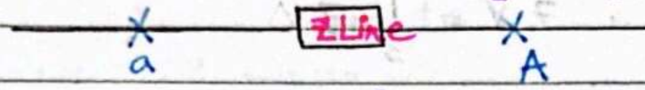
$\boxed{1}$ Balanced [Y - Y] connection :-

- Source → Y-connected.
  Load → Y-connected.



∴ Note :-

- يمكن نحط بين [Y-Y] ← ZLine وممكن لا .



مثال .

- السلك المحايد [nN] وعادة ما يتم تأريضه في النظام المتزن ويكون [جهده = صفر] وتهمل مقاومته .
- [I Line] ← هو التيار المار في خط من الخطوط .
- [I phase] ← هو التيار المار في المصدر [source] .

- phase voltages :-

$V_{an} = V_p \angle 0^\circ \ V$.

$V_{bn} = V_p \angle -120^\circ \ V$. For [+ve sequence]

$V_{cn} = V_p \angle 120^\circ \ V$.

- In [Y-Y] connected :-

$V_{Line} = \sqrt{3}\, V_\phi \angle 30^\circ$ ... ①

$V_\phi = \dfrac{V_{Line} \angle -30^\circ}{\sqrt{3}}$ ... ②

sol :- - Line voltages :-

$V_{ab} = V_{an} - V_{bn} = \sqrt{3}\, V_{an} \angle 0^\circ + 30^\circ$

$= \sqrt{3}\, V_p \angle 30^\circ \ V$.

$V_{bc} = V_{bn} - V_{cn} = \sqrt{3}\, V_{bn} \angle -120^\circ + 30^\circ$

$= \sqrt{3}\, V_p \angle -90^\circ \ V$.

$V_{ca} = V_{cn} - V_{an} = \sqrt{3}\, V_{cn} \angle 120^\circ + 30^\circ$

$= \sqrt{3}\, V_p \angle 150^\circ \ V$.

- Line currents :-

$I_a = \dfrac{V_{an}}{Z_Y} \ A$.

$$I_b = \frac{V_{bn}}{Z_Y}\ A.$$

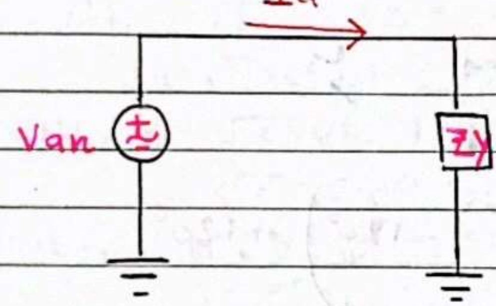
$$I_c = \frac{V_{cn}}{Z_Y}\ A.$$

- In [Y-Y] connected :-

$$I_{Line} = I_\phi$$

- طريقة أخرى لحساب الـ [line currents] :-

بناخذ مصدر جهد واحد مع Load واحد ويتحول الدارة عبارة عن [single phase] :-



- KVL at the Loop :-

$$I_a = \frac{V_{an}}{Z_Y}\ A.$$ وهكذا ...

∴ Note :-

- $V_{Line} > V_\phi$.
- In +ve sequence :-
  Line voltage Leads phase voltage by 30°.
- In -ve sequence :-
  Line Voltage Lags phase voltage by 30°.

Because it is a balanced system :-

$$I_a + I_b + I_c = I_{nN} = zero$$

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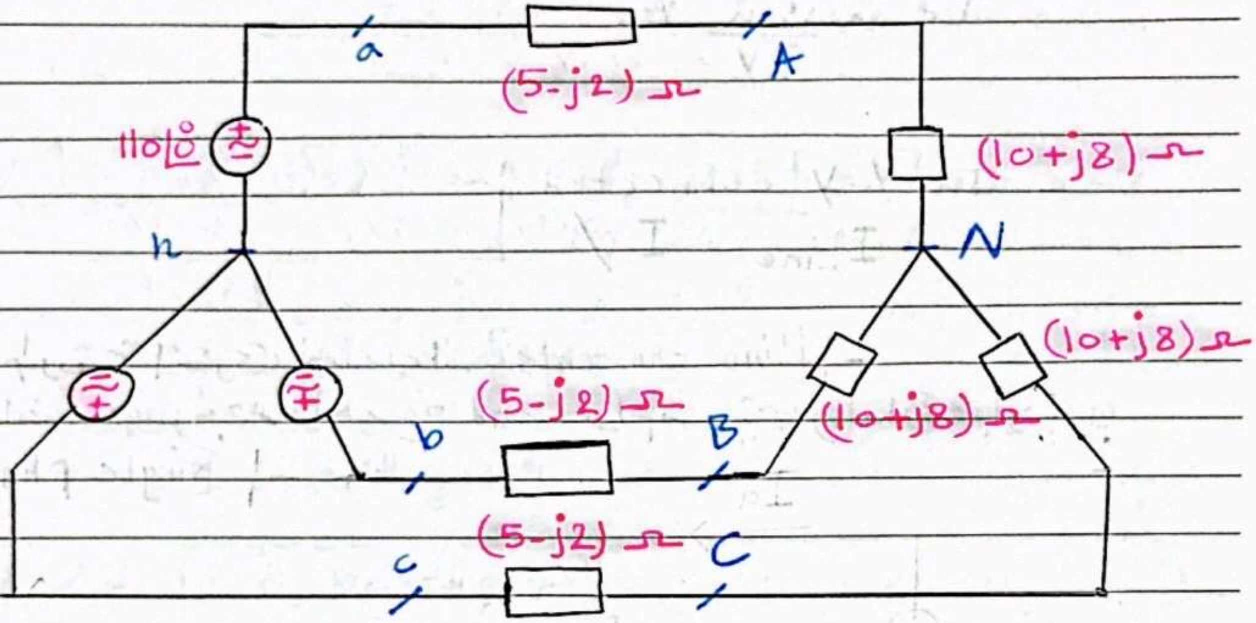
① :- calculate the Line currents in 3 wire [Y-Y] system :-



- $V_{an} = 110\angle 0^\circ$ V.
$V_{bn} = 110\angle -120^\circ$ V.
$V_{cn} = 110\angle 120^\circ$ V.
-120°
+120°
For [+ve sequence].

- Line currents :-

$$I_a = \frac{V_{an}}{Z_Y + Z_{Line}} = \frac{110\angle 0^\circ}{(10+j8)+(5-j2)}$$

$$= \frac{110\angle 0^\circ}{16.15\angle 21.8^\circ} = 6.81\angle -21.8^\circ \text{ A.}$$

$$I_b = \frac{V_{bn}}{Z_Y + Z_{Line}} = \frac{110\angle -120^\circ}{16.15\angle 21.8^\circ} = 6.81\angle -141.8^\circ \text{ A.}$$

$$I_c = \frac{V_{cn}}{Z_Y + Z_{Line}} = \frac{110\angle 120^\circ}{16.15\angle 21.8^\circ} = 6.81\angle 98.2^\circ \text{ A.}$$

Q :- For a 3 phase [Y-Y] connection system , if $V_{an} = 200$ Vrms / $Z_L = 100 \angle 60^\circ \ \Omega$ / +ve sequence :-

- Find Line and phase currents and Voltages.
- Calculate total power dissipated in Load.

- phase voltages :-

$V_{an} = 200 \angle 0^\circ$ Vrms.

$V_{bn} = 200 \angle -120^\circ$ Vrms.

$V_{cn} = 200 \angle -240^\circ = 200 \angle 120^\circ$ Vrms.

- Line voltages :-

$V_{ab} = \sqrt{3}\, V_{an} \angle 30^\circ$

$= \sqrt{3} \times 200 \angle 0^\circ + 30^\circ = 200\sqrt{3} \angle 30^\circ$ vrms.

$V_{bc} = \sqrt{3}\, V_{bn} \angle 30^\circ$

$= \sqrt{3} \times 200 \angle -120^\circ + 30^\circ = 200\sqrt{3} \angle -90^\circ$ Vrms.

$V_{ca} = \sqrt{3}\, V_{cn} \angle 30^\circ$

$= \sqrt{3} \times 200 \angle 120^\circ + 30^\circ = 200\sqrt{3} \angle 150^\circ$ vrms.

- Line currents & phase currents :-

$I_{Line} = I_\phi$

so :- $I_a = \frac{V_{an}}{Z_L} = \frac{200 \angle 0^\circ}{100 \angle 60^\circ} = 2 \angle -60^\circ$ A.

$I_b = \frac{V_{bn}}{Z_L} = \frac{200 \angle -120^\circ}{100 \angle 60^\circ} = 2 \angle -180^\circ$ A.

$I_c = \frac{V_{cn}}{Z_L} = \frac{200 \angle -240^\circ}{100 \angle 60^\circ} = 2 \angle -300^\circ$ A.

-120°

-120°

∴ Note :-

P_{avg} total for 3ϕ system $= 3 V_\phi I_\phi \cos(\theta_{V_\phi} - \theta_{I_\phi})$ ... (1)

P_{avg} per phase $= V_\phi I_\phi \cos(\theta_{V_\phi} - \theta_{I_\phi})$ ... (2)

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- total avg power for 3ϕ system :-

$$P_{avg} = 3 V_\phi I_\phi \cos(\theta_{V\phi} - \theta_{I\phi})$$
$$= 3 \times 200 \times 2 \times \cos(\text{zero}^\circ - -60^\circ)$$
$$= 600 \text{ watt}.$$

Q :- 3 ϕ [Y-Y] connected system, $V_{ab} = 400 \angle 0^\circ$ Vrms, +ve sequence, $Z_L = [j100 // 100 // 50+j50]$

Find :-

a- phase voltages.

b- Line currents.

c- total avg power dissapated in Load.

a- phase voltages :-

$$V_\phi = \frac{V_{Line} \angle -30^\circ}{\sqrt{3}}$$

$$V_{an} = \frac{V_{ab} \angle -30^\circ}{\sqrt{3}} = \frac{400 \angle -30^\circ + 0^\circ}{\sqrt{3}}$$

$V_{an} = 231 \angle -30^\circ$ Vrms.

$V_{bn} = 231 \angle -150^\circ$ Vrms.

$V_{cn} = 231 \angle -270^\circ = 231 \angle 90^\circ$ Vrms.

b- Line currents :-

$$I_a = \frac{V_{an}}{Z_L} = \frac{231 \angle -30^\circ}{[-j100 // 100 // 50+j50]} = \frac{231 \angle -30^\circ}{50}$$
$$= 4.618 \angle -30^\circ \text{ A}.$$

$I_b = 4.618 \angle -150^\circ$ A.

$I_c = 4.618 \angle 90^\circ$ A.

c- Total avg power for 3ϕ system :-

$$P_{avg} = 3 V_\phi I_\phi \cos(\theta_{V\phi} - \theta_{I\phi})$$
$$= 3 \times 231 \times 4.618 \cos(-30^\circ - -30^\circ)$$
+
$$= 3200.3 \text{ W}.$$

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Q :- A balanced 3ϕ [Y-Y] system , $V_{Line} = 300V$, supplying total Load with 1200W , at 0.8 Leading pF , Find I_L per phase impedence :-

- $V_\phi = \dfrac{V_{Lin} \angle -30^\circ}{\sqrt{3}} = \dfrac{300 \angle -30^\circ}{\sqrt{3}} = 173.2 \angle -30^\circ V.$

- $P_{total} = 3 V_\phi I_\phi \cos(\theta V_\phi - \theta I_\phi)$

  $1200 = 3 \times 173.2 \, I_\phi \times 0.8$

  $I_\phi = I_{Line} = 2.89 A.$

- $\cos^{-1} pF = \theta = \cos^{-1}(0.8) = 36.9^\circ.$

  For Leading pF $\longrightarrow \theta = -36.9^\circ.$

- $\cos^{-1} pF = \theta v - \theta i$

  $-36.9^\circ = -30^\circ - \theta i$

  so :- $\theta i = 6.9^\circ.$

- $I_a = 2.89 \angle 6.9^\circ A.$

  $I_b = 2.89 \angle -113.1^\circ A.$

  $I_c = 2.89 \angle -233.1^\circ A.$

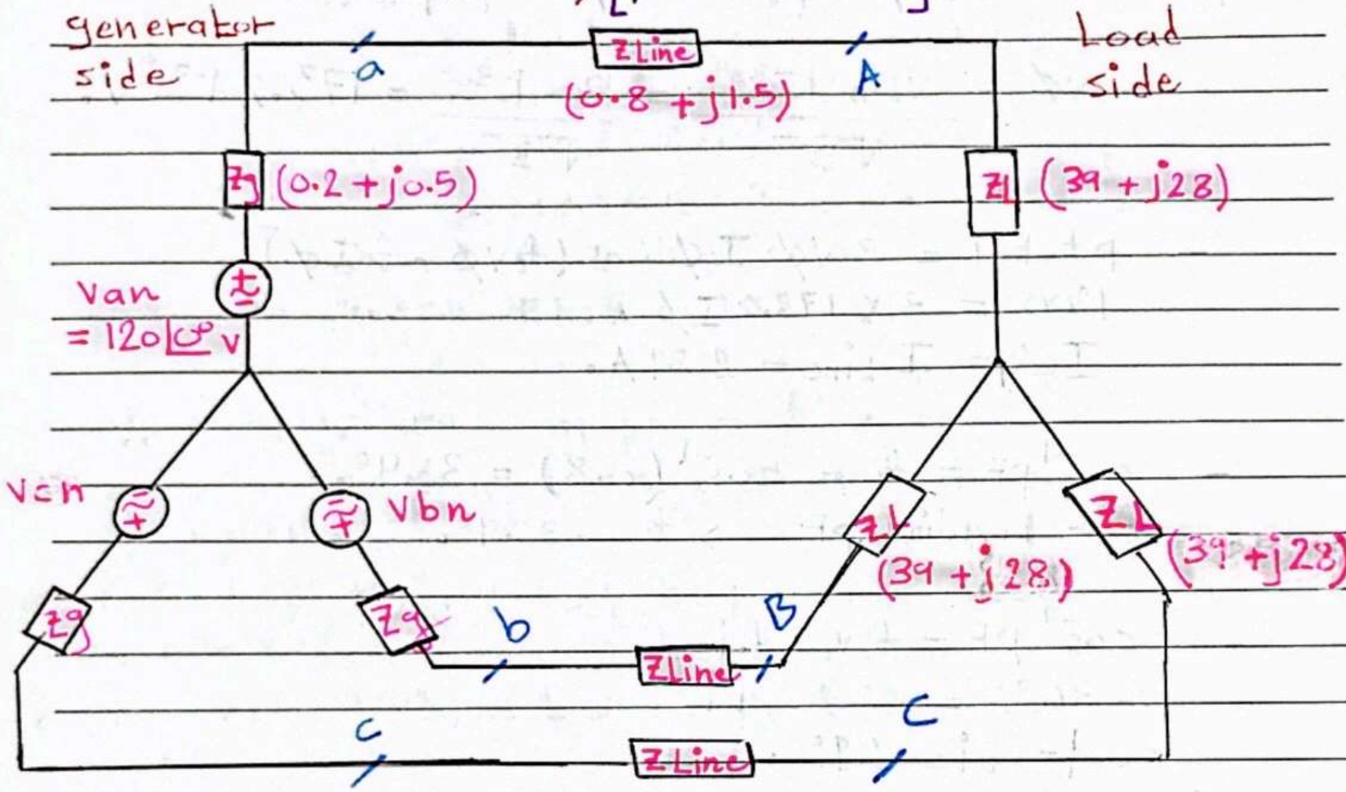
Q :- A 3 phase Y-connected generator , has an impedence of $Z_g = [0.2 + j0.5] \Omega$ the internal phase Voltage of the generator is 120V , the generator feeds a balanced 3 phase Y-connected Load $Z_L = [39 + j28] \Omega$, $Z_{Line} = [0.8 + j1.5] \Omega$:-

a) construct the single phase equivalent circuit.

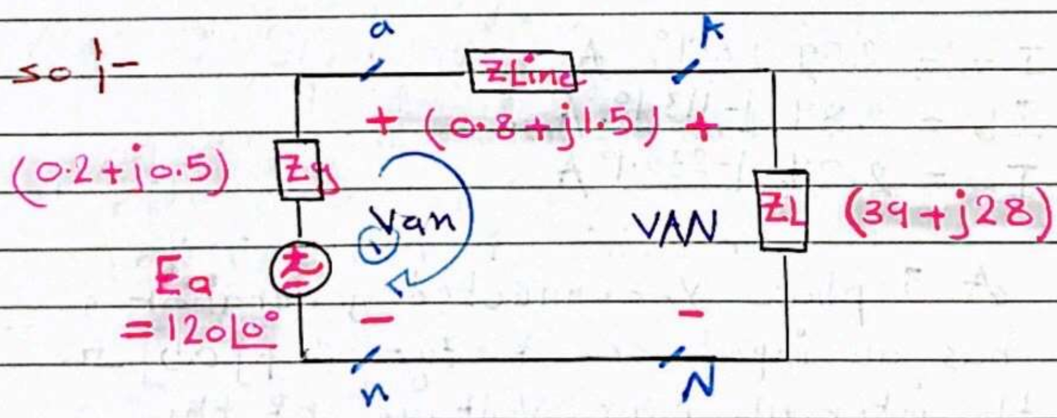
- بالبداية لازم أرسم [3 ϕ connection system] :-

source → [Y-connected].

Load → [Y-connected].



sol:-



b) The Line currents.

$I_{Line} = I_\phi$

- phase voltages :-

$V_{an} = 120 \angle 0° \ V$.

$V_{bn} = 120 \angle -120° \ V$.

$V_{cn} = 120 \angle -240° = 120 \angle +120° \ V$.

without Zg

– Line currents :-

$$I_a = \frac{V_{an}}{Z_g + Z_{Line} + Z_{Load}} = \frac{120\angle 0^\circ}{0.2 + j0.5 + 0.8 + j1.5 + 39 + j28}$$

$$= \frac{120\angle 0^\circ}{40 + j30} = 2.4\angle -36.86^\circ \text{ A.}$$

By shifting I_a by -120° :-

$$I_b = I_a \angle -120^\circ = 2.4\angle -120^\circ - 36.86^\circ = 2.4\angle -156.87^\circ \text{ A.}$$

By shifting I_b by -120° :-

$$I_c = I_b \angle -120^\circ = 2.4\angle -156.87^\circ - 120^\circ = 2.4\angle -276.87 \text{ A.}$$

c) phase voltage at the Load terminals.

$$V_{AN} = I_a \times Z_L$$

$$= 2.4\angle -36.86^\circ \times (39 + j28)$$

$$= 115.22\angle -1.19^\circ \text{ V.}$$

$$V_{BN} = 115.22\angle -1.19^\circ - 120^\circ$$

$$= 115.22\angle -121.19^\circ \text{ V.}$$

1 $V_{CN} = 115.22\angle -121.19^\circ - 120^\circ$

$$= 115.22\angle -241.19^\circ \text{ V.}$$

or 2 $V_{CN} = 115.22\angle -1.19^\circ + 120^\circ$

$$= 115.22\angle 118.81^\circ \text{ V.}$$

d) The Line voltage at Load terms.

$$V_{Line} = \sqrt{3}\, V\phi \angle 30^\circ$$

so :- $V_{AB} = \sqrt{3}\, V_{AN} \angle 30^\circ$

$$= \sqrt{3} \times 115.22\angle 30^\circ - 1.19^\circ$$

$$= 199.58\angle 28.81^\circ \text{ V.}$$

$$V_{BC} = 199.58\angle 28.81^\circ - 120^\circ$$

$$= 199.58\angle -91.19^\circ \text{ V.}$$

$$V_{CA} = 199.58\angle 28.81^\circ + 120^\circ$$

$$= 199.58\angle 148.81^\circ \text{ V.}$$

e) phase voltage at the generator.

- KVL at Loop 1 :-

$-120\angle 0^\circ + V_{an} + [0.2 + j0.5] I_a = \text{Zero}$

$V_{an} = 120\angle 0^\circ + 2.4\angle -36.86^\circ \times [0.2 + j0.5]$

$= 118.9 \angle -0.32^\circ \text{ V}.$

$V_{bn} = 118.9 \angle -120^\circ - 0.32^\circ$

$= 118.9 \angle -120.32^\circ \text{ V}.$

$V_{cn} = 118.9 \angle +120^\circ - 0.32^\circ$

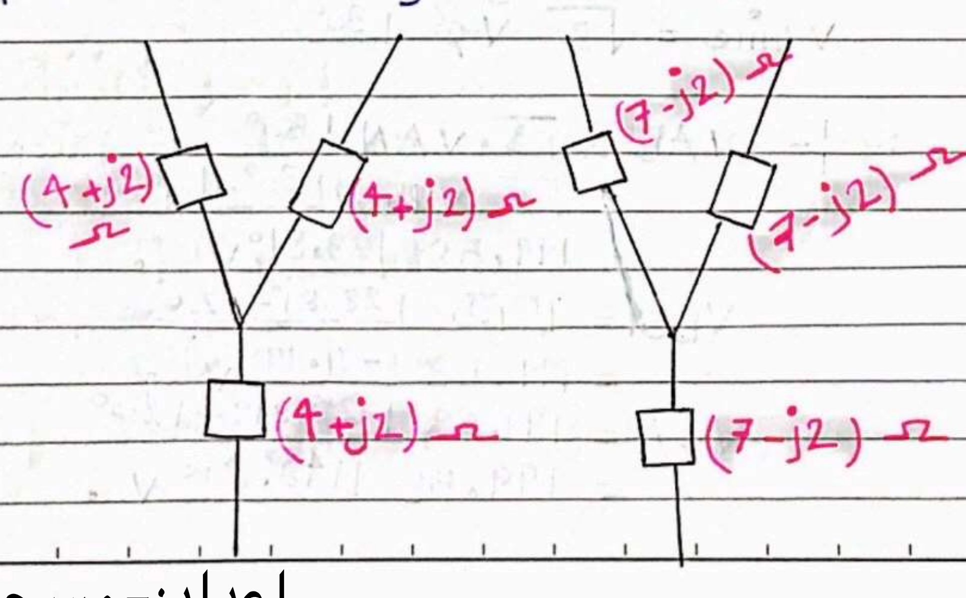
$= 118.9 \angle 119.68^\circ \text{ V}.$

∴ Note :-

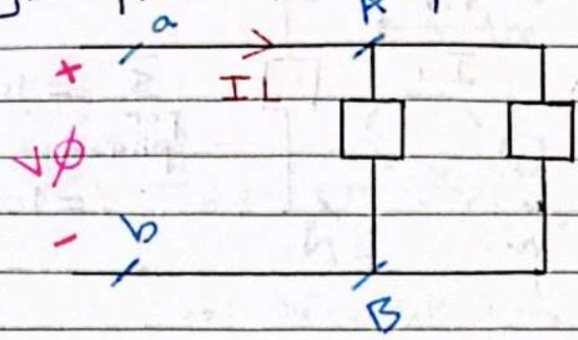
- يجب الانتباه جيداً إلى المطلوب إذا كان [at the load] او [at the generator].

- عند وجود [impedence] موصولة مع [3φ generators] وهي ما تسمى بـ [generator impedence] فإن حساب المولتية يختلف فعند حساب الـ [phase voltage] نأخذ بعين الاعتبار وجود [Zg].

⑦ :- VLine = 500 V, 2 balanced Y-connected Loads parallel, one is capacitive [7-j2] Ω /phase, the other is inductive [4+j2] Ω, Find phase voltage, Line current, total power drawn by the source :-



- per single phase for capacitive and inductive :-



- phase voltage :-

$$V\phi = \frac{V_{Line} \angle -30^\circ}{\sqrt{3}}$$

so :- $V\phi = \frac{500 \angle 0^\circ - 30^\circ}{\sqrt{3}} = 288.68 \angle -30^\circ$ V.

- Line current :-

$I_{Line} = I\phi$

so :- $I_{line} = \frac{V\phi}{Z_{eq}} = \frac{288.68 \angle -30^\circ}{[4+j2] // [7-j2]}$

$$= \frac{288.68 \angle -30^\circ}{3 \angle 10.62^\circ} = 96.3 \angle -40.62^\circ \text{ A}.$$

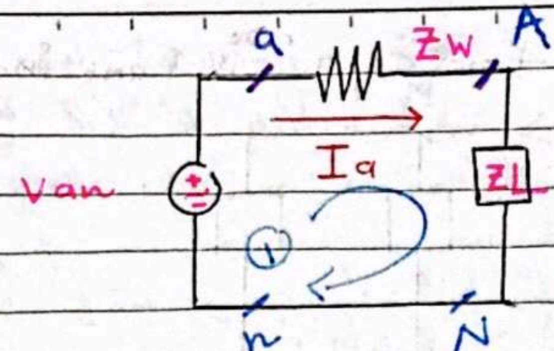
- total avg power :-

$$P_{3\phi} = 3 V\phi I\phi \cos(\theta V\phi - \theta I\phi)$$

$$= 3 \times 288.68 \times 96.3 \times \cos(-30^\circ + 40.62^\circ)$$

$$= 81971.105 \text{ W}.$$

Q :- If $V_{an} = 2300$ Vrms, balanced [Y-Y] connected, $R_W = 2\ \Omega$, +ve sequence, total power drawn by the source [100+j30 KVA], find I_a / V_{AN} / $Z\phi$ / efficiency :-



$$\tilde{S}_{\text{per phase}} = \frac{100 + j30}{3} K$$

$$= 104.4 \angle 16.69^\circ \text{ KVA.}$$

- I_a ?!

$$\tilde{S} = V I^*$$

$$104.4 \angle 16.69^\circ = 2300 \times I^*$$

sol:- $I^* = 15.13 \angle 16.69^\circ$ A.

$$I_a = 15.13 \angle -16.69^\circ \text{ A.}$$

- VAN ?!

$$-van + VAN + I_a \times R_W$$

$$VAN = 2300 - [15.13 \angle -16.69^\circ \times 2$$

$$= 2271 \angle 0.219^\circ \text{ V.}$$

- Z per phase ?!

$$Z\phi = \frac{VAN}{I_a} = \frac{2271 \angle 0.219^\circ}{15.13 \angle -16.69^\circ} = [143.3 + j44.3]$$

R X

$$= 150 \angle 16.9^\circ \ \Omega.$$

- efficiency ?!
- $p_{\text{input per phase}} = \frac{100K}{3} = 33.33\text{KW.}$

source

كيف؟

$$\tilde{S} = [100 + j30] \text{ KVA}$$

pavg ϕ

- $p_{\text{out For Load}} = I_a^2 \times R$

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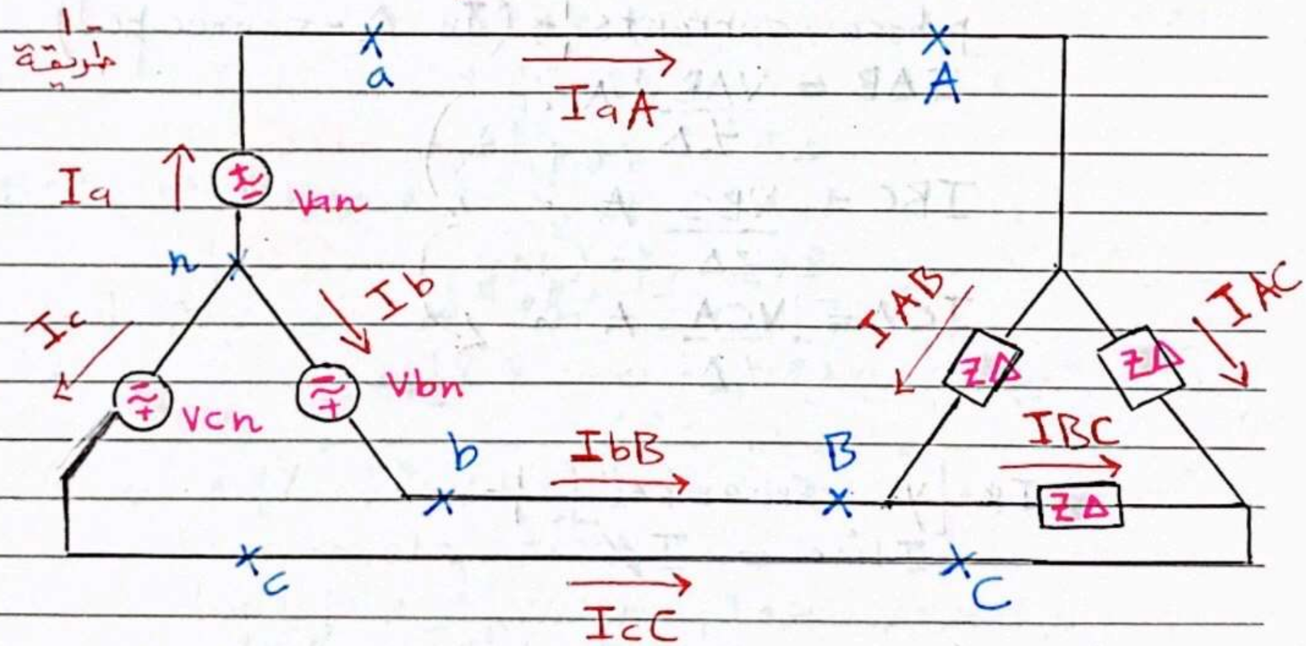
$P_{out} = (15.13)^2 \times 143.3 = 32.8\ Kw.$
For Load

sol:- $efficiency = \frac{P_{out}}{P_{in}} \times 100\%$

$= \frac{32.8 \times 10^3}{33.33 \times 10^3} \times 100\% = 98.4\%$

$\boxed{2}$ Balanced [Y-Δ] connection :-

- Source → Y-connected.
  Load → Δ-connected.



- phase voltages :- (In Y-connected)
  $V_{an} = V_P \angle 0^\circ\ V.$
  $V_{bn} = V_P \angle -120^\circ\ V.$ For [+ve sequence]
  $V_{cn} = V_P \angle 120^\circ\ V.$

- In [Y-connected] :-

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$V_{Line} = \sqrt{3}\, V_\phi \angle 30^\circ$ ... (1)

so :- $V_\phi = \dfrac{V_{Line} \angle -30^\circ}{\sqrt{3}}$ ... (2)

so :- Line Voltages :- (In y-connected)

$V_{ab} = \sqrt{3}\, V_p \angle 30^\circ$ V.

$V_{bc} = \sqrt{3}\, V_p \angle -90^\circ$ V.

$V_{ca} = \sqrt{3}\, V_p \angle -210^\circ = \sqrt{3}\, V_p \angle 150^\circ$ V.

- $V_{ab} = V_{AB}$ v.
  $V_{bc} = V_{BC}$ v. [parallel]
  $V_{ca} = V_{CA}$ v.

- phase currents :- (In Δ-connected)

$I_{AB} = \dfrac{V_{AB}}{Z_\Delta}$ A.

-120°

$I_{BC} = \dfrac{V_{BC}}{Z_\Delta}$ A.

-120°

$I_{CA} = \dfrac{V_{CA}}{Z_\Delta}$ A.

- In [y-connected] :-
  $I_{Line} = I_\phi$

so :- Line currents :-

$I_a = I_{aA}$.

$I_b = I_{bB}$.

$I_c = I_{cC}$.

so :- In [Δ-connected] :-

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$I_{Line} = \sqrt{3}\, I_\phi \angle{-30^\circ}$ ... (1)

الإثبات

so :- $I_a = I_{AB} - I_{CA}$

$\because I_{CA} = I_{AB} \angle{-240^\circ}$

$I_a = I_{AB} - I_{AB} \angle{-240^\circ} = I_{AB} [1 - 1 \angle{-240^\circ}]$

$I_a = \sqrt{3} I_{AB} \angle{-30^\circ}$ A.

so :- $I_a = \sqrt{3}\, I_{AB} \angle{-30^\circ}$ A.

$I_b = \sqrt{3}\, I_{BC} \angle{-30^\circ}$ A.

$I_c = \sqrt{3}\, I_{CA} \angle{-30^\circ}$ A.

2- طريقة

نقوم بتحويل الـ [Loads] من [$\Delta \rightarrow Y$] عن طريق :- [$Z\Delta = 3 ZY$] ومن ثم يحل السؤال على طريقة [Y-Y].

∴ Note :-

- توصيلة الـ [Y - Y] هي أساس التوصيلات وأهمها بحيث أنني أستطيع تحويل أي توصيلة إلى توصيلة [Y-Y].
- في حال وجود [Z Line] بين توصيلة الـ [source] وتوصيلة الـ [Load] لا بد من تحويل التوصيلة إلى [Y-Y connected] ولا تحل إلا بهذه الطريقة.

Ⓠ :- A [Y-connected] source with $V_{an} = 100 \angle{10^\circ}$ V, is connected to [Δ-connected] balanced load [8 + j4] Ω per phase, calculate the phase and line currents :-

Method I

- phase voltages :-

$V_{an} = 100 \angle{10^\circ}$ V.

$V_{bn} = 100 \angle{10^\circ - 120^\circ} = 100 \angle{-110^\circ}$ V.

$V_{cn} = 100 \angle{-110^\circ - 120^\circ} = 100 \angle{-230^\circ}$ V.

- Line voltages :-

$V_{AB} = V_{ab} = \sqrt{3}\ V_{an} \angle 30^\circ$

$= \sqrt{3} \times 100 \angle 110^\circ + 30^\circ$

$= 173.2 \angle 140^\circ$ V.

$V_{BC} = V_{bc} = \sqrt{3}\ V_{bn} \angle 30^\circ$

$= \sqrt{3} \times 100 \angle 30^\circ - 110^\circ$

$= 173.2 \angle -80^\circ$ V.

$V_{CA} = V_{ca} = \sqrt{3}\ V_{cn} \angle 30^\circ$

$= \sqrt{3} \times 100 \angle 30^\circ - 230^\circ$

$= 173.2 \angle -200^\circ$ V.

- phase currents :-

$I_{AB} = \frac{V_{AB}}{Z\Delta} = \frac{173.2 \angle 140^\circ}{[8+j4]} = 19.36 \angle 113.43^\circ$ A.

$I_{BC} = \frac{V_{BC}}{Z\Delta} = \frac{173.2 \angle -80^\circ}{[8+j4]} = 19.36 \angle -106.57^\circ$ A.

$I_{CA} = \frac{V_{CA}}{Z\Delta} = \frac{173.2 \angle -200^\circ}{[8+j4]} = 19.36 \angle 133.43^\circ$ A.

- Line currents :-

$I_a = \sqrt{3}\ I_{AB} \angle -30^\circ$

$= \sqrt{3} \times 19.36 \angle -30^\circ + 13.43^\circ$

$= 33.53 \angle -16.57^\circ$ A.

$I_b = \sqrt{3}\ I_{BC} \angle -30^\circ$

$= \sqrt{3} \times 19.36 \angle -30^\circ + -106.57^\circ$

$= 33.53 \angle -136.57^\circ$ A.

$I_c = \sqrt{3}\ I_{CA} \angle -30^\circ$

$= \sqrt{3} \times 19.36 \angle -30^\circ + 133.430^\circ$

$= 33.53 \angle 103.43^\circ$ A.

Method [2] — $Zy = \frac{Z\Delta}{3} = \left[\frac{8+j4}{3}\right] = \frac{8.94\angle 26.57^\circ}{3}$

$= 2.98\angle 26.57^\circ \ \Omega.$

— phase currents :-

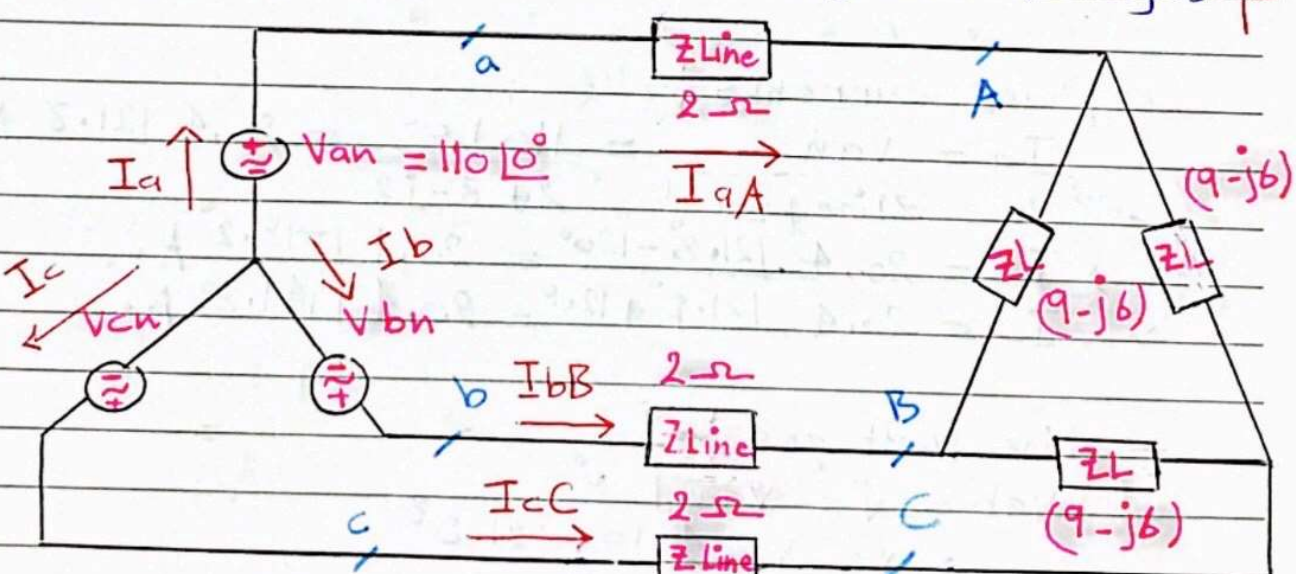
$Ia = \frac{Van}{Zy} = \frac{100\angle 0^\circ}{2.98\angle 26.57^\circ} = 33.54\angle -16.57^\circ \ A.$

$Ib = 33.54\angle -136.57^\circ \ A.$

$Ic = 33.54\angle -256.57^\circ \ A.$

— $I_{Line} = I_\phi$

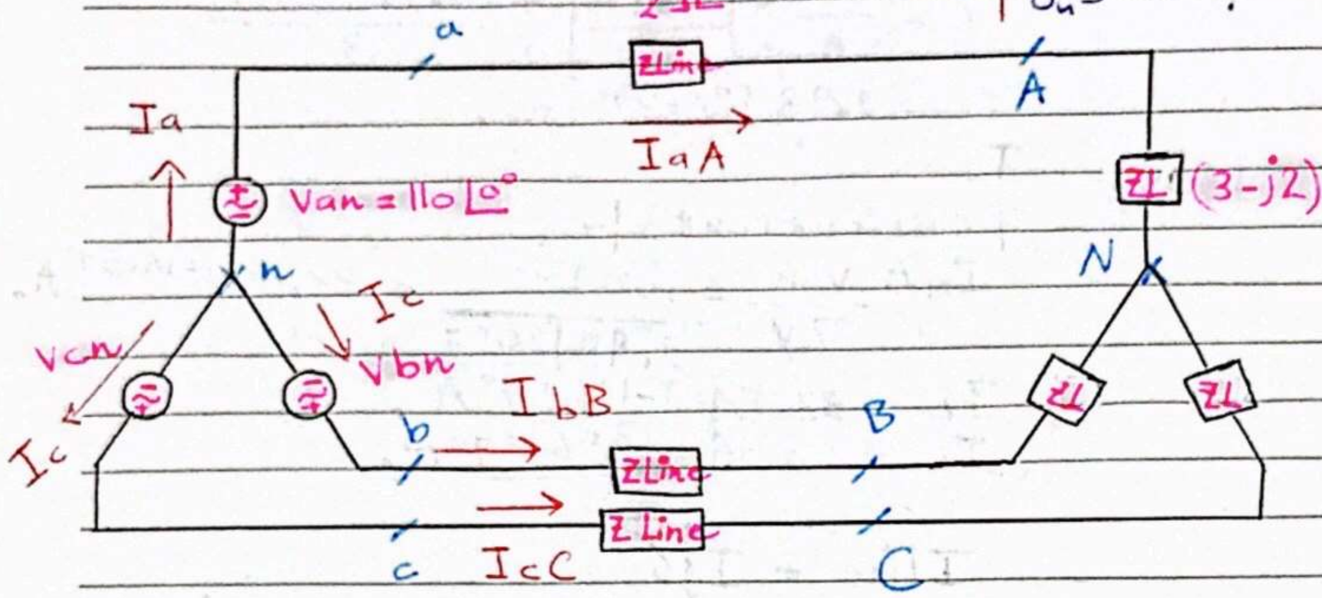
Q :- A [Y-connected] source with $van = 110\angle 0^\circ$ V, is connected to [Δ-Connected] balanced Load [9-j6] Ω per phase, ZLine = 2 Ω, Find phase and Line currents and voltages :-



مبدئياً هون لازم أحول من توصيلة [Y-Δ connected] إلى توصيلة [Y-Y connected] لأنه يوجد (ZLine).

$ZY = \frac{Z\Delta}{3} = \frac{9-j6}{3} = [3-j2] \ \Omega.$

- بعد التحويل :-



- phase voltages :-

$V_{an} = 110 \angle 0° \, V$.

$V_{bn} = 110 \angle -120° \, V$.

$V_{cn} = 110 \angle +120° \, V$.

- Phase currents :-

$I_a = \dfrac{V_{an}}{Z_{Line} + Z_{Load}} = \dfrac{110 \angle 0°}{2 + 3 - j2} = 20.4 \angle 21.8° \, A$.

$-120°$

$+120°$

$I_b = 20.4 \angle 21.8° - 120° = 20.4 \angle -98.2° \, A$.

$I_c = 20.4 \angle 21.8° + 120° = 20.4 \angle 141.8° \, A$.

- Line voltages :-

$V_{ab} = \sqrt{3} \, V_{an} \angle 30°$

$= \sqrt{3} \times 20.4 \angle 30° + zero°$

$= 35.3 \angle 30° \, V$.

$V_{bc} = 35.3 \angle 30° - 120° = 35.3 \angle -90° \, V$.

$V_{ca} = 35.3 \angle 30° + 120° = 35.3 \angle 150° \, V$.

- Line currents :-

$I_{aA} = I_a = 20.4 \angle 21.8^\circ A.$

$I_{bB} = I_b = 20.4 \angle -98.2^\circ A.$

$I_{cC} = I_c = 20.4 \angle 141.8^\circ A.$

- $I_{AB} = \frac{I_a \angle 30^\circ}{\sqrt{3}} = \frac{20.4 \angle 30^\circ + 21.8^\circ}{\sqrt{3}} = 11.7 \angle 51.8^\circ A.$

$I_{BC} = 11.7 \angle 51.8^\circ - 120^\circ = 11.7 \angle -68.2^\circ A.$

$I_{CA} = 11.7 \angle 51.8^\circ + 120^\circ = 11.7 \angle 171.8^\circ A.$

so :- [IAB / IBC / ICA] are the Line currents in [Δ-connected].

- $V_{AB} = I_{AB} \times Z_\Delta = [11.7 \angle 51.8^\circ] \times [9 - j6]$

$= 126.55 \angle 18.11^\circ V.$

$V_{BC} = 126.55 \angle 18.11^\circ - 120^\circ = 126.55 \angle -101.89^\circ V.$

$V_{CA} = 126.55 \angle 18.11^\circ + 120^\circ = 126.55 \angle 138.11^\circ V.$

- ما بجيز هون احكي إنه [VAB = vab] لوجود ال [Z Line].

Q :- A Balanced 3Ø [y-Δ connected], RW = 0, $V_{an} = 200 \angle 60^\circ$ vrms, power per phase $= 2 - j$ KVA, +ve sequence, Find :-

Vbc / ZØ / IaA :-

- $v_{ab} = \sqrt{3}\, v_{an} \angle 30^\circ$

$= \sqrt{3} \times 200 \angle 30^\circ + 60^\circ = 346.4 \angle 90^\circ V.$

so :- $V_{bc} = 346.4 \angle 90^\circ - 120^\circ = 346.4 \angle -30^\circ V.$

- $S = V_{AB} \times I_{AB}^*$

$V_{AB} = V_{ab} \longrightarrow$ parallel

sol:- $I_{AB}^* = \dfrac{[2-j]K}{346.4\angle 90^\circ} = 6.455\angle -116.565^\circ$ A.

$I_{AB} = 6.455\angle 116.565^\circ$ A.

sol:- $Z_\phi = \dfrac{V_{AB}}{I_{AB}} = \dfrac{346.4\angle 90^\circ}{6.455\angle 116.565^\circ}$

$= 53.67\angle -26.65^\circ\ \Omega$.

- $I_{aA} = I_a = \sqrt{3}\, I_{AB}\angle -30^\circ$

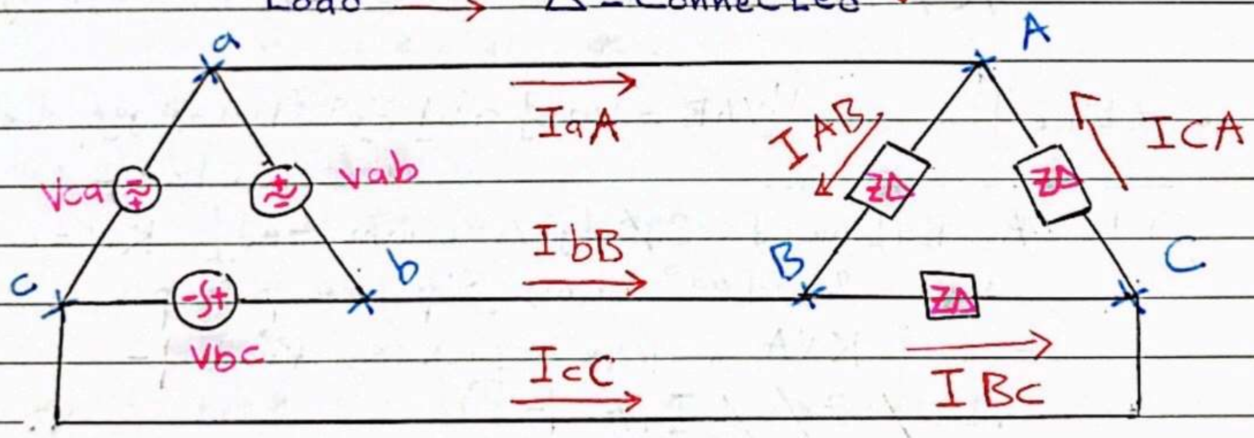
$= \sqrt{3} \times 6.455\angle -30^\circ + 116.565^\circ$

$= 11.18\angle 86.57^\circ$ A

[3] Balanced [Δ-Δ] connection :-

- source $\longrightarrow$ Δ-connected.

Load $\longrightarrow$ Δ-connected.



- In [Δ-connected] :-

$V_\phi = V_{Line}$

- phase voltages :-

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$V_{ab} = V_p \angle 0^\circ$ V.
$V_{bc} = V_p \angle -120^\circ$ V.
$V_{ca} = V_p \angle 120^\circ$ V.

- $V_{ab} = V_{AB}$.
  $V_{bc} = V_{BC}$. [parallel]
  $V_{ca} = V_{CA}$.

- phase currents :-
  $I_{AB} = \dfrac{V_{AB}}{Z_\Delta}$ A.

  $I_{BC} = \dfrac{V_{BC}}{Z_\Delta}$ A.

  $I_{CA} = \dfrac{V_{CA}}{Z_\Delta}$ A.

- Line currents :-
  $I_{aA} = I_{AB} - I_{BC}$.
  $I_{bB} = I_{BC} - I_{AB}$.
  $I_{cC} = I_{CA} - I_{BC}$.

or :- $I_{aA} = \sqrt{3}\, I_{AB} \angle -30^\circ$ A.
$I_{bB} = \sqrt{3}\, I_{BC} \angle -30^\circ$ A.
$I_{cC} = \sqrt{3}\, I_{CA} \angle -30^\circ$ A.

2 :- A [Δ-connected] Load having [$Z_L = 20 - j15$], is connected to [Δ-connected] generator, $V_{ab} = 330 \angle 0^\circ$ V, Find phase currents of Load and Line currents :-

- $V_{ab} = V_{AB} = 330 \angle 0^\circ$ V.

sol:- - phase currents :-

$$I_{AB} = \frac{V_{AB}}{Z_\Delta} = \frac{330\angle 0^\circ}{[20-j15]} = 13.2\angle 36.86^\circ\ A.$$

$$I_{BC} = 13.2\angle 36.86^\circ - 120^\circ = 13.2\angle -83.13^\circ\ A.$$

$$I_{CA} = 13.2\angle 36.86^\circ + 120^\circ = 13.2\angle 156.86^\circ\ A.$$

- Line currents :-

$$I_a = I_{aA} = \sqrt{3}\, I_{AB}\angle -30^\circ$$

$$= \sqrt{3} \times 13.2\angle -30^\circ + 36.86^\circ$$

$$= 22.86\angle 6.87^\circ\ A.$$

$$I_b = I_{bB} = 22.86\angle 6.87^\circ - 120^\circ = 22.86\angle -113.13^\circ\ A.$$

$$I_c = I_{cC} = 22.86\angle 6.87^\circ + 120^\circ = 22.86\angle 126.87^\circ\ A.$$

Q :- A 3ϕ [Δ-Δ connected], $I_a = 9.609\angle 35^\circ$, $Z_\Delta = [18+j12]\ \Omega$, Find I_{AB} / V_{AB} :-

$$- I_{AB} = \frac{I_a\angle 30^\circ}{\sqrt{3}} = \frac{9.609\angle 35^\circ + 30^\circ}{\sqrt{3}}$$

$$= 5.54\angle 65^\circ\ A.$$

$$- V_{AB} = I_{AB} \times Z_\Delta$$

$$= 5.54\angle 65^\circ \times [18+j12]$$

$$= 120\angle 98.69^\circ\ V.$$

Q :- Find the Line and phase currents, assume that the $Z_{Load} = [12+j9]\ \Omega$ per phase, if the connection is [Δ-Δ connected], $V_{AB} = 210\angle 0^\circ\ V$.

- phase currents :-

$$I_{AB} = \frac{V_{AB}}{Z_\Delta} = \frac{210\angle 0^\circ}{[12+j9]} = 14\angle -36.8^\circ\ A.$$

$I_{BC} = 14 \angle -36.8° - 120° = 14 \angle -156.8°$ A.
$I_{CA} = 14 \angle -36.8° + 120° = 14 \angle 83.2°$ A.

- Line currents :-
$I_a = I_{aA} = \sqrt{3}\, I_{AB} \angle -30°$
$= \sqrt{3} \times 14 \angle -30° - 36.8°$
$= 24.25 \angle -66.87°$ A.
$I_b = I_{bB} = 24.25 \angle -66.87° - 120°$
$= 24.25 \angle -186.87°$ A.
$I_c = I_{cC} = 24.25 \angle -66.87° + 120°$
$= 24.25 \angle 53.13°$ A.

Q :- A 3ϕ system , $V_L = 300$ supplies total power 1200 W to Δ-connection Load at 0.8 Lagging pF, Find [I_L / Z] per phase :-
$I_L = I_\phi$

- $P_{avg\ total} = 3 V_\phi I_\phi \cos(\theta_{V\phi} - \theta_{I\phi})$
$1200 = 3 \times 300 \times I_\phi \times 0.8$
so :- $I_\phi = 1.67$ A.

- $\theta_Z = \cos^{-1} pF = \cos^{-1}(0.8) = 36.87°$.

so :- $\theta_Z = \theta_V - \theta_i$
$36.86° = \text{Zero} - \theta_i$
$\theta_i = -36.87°$.

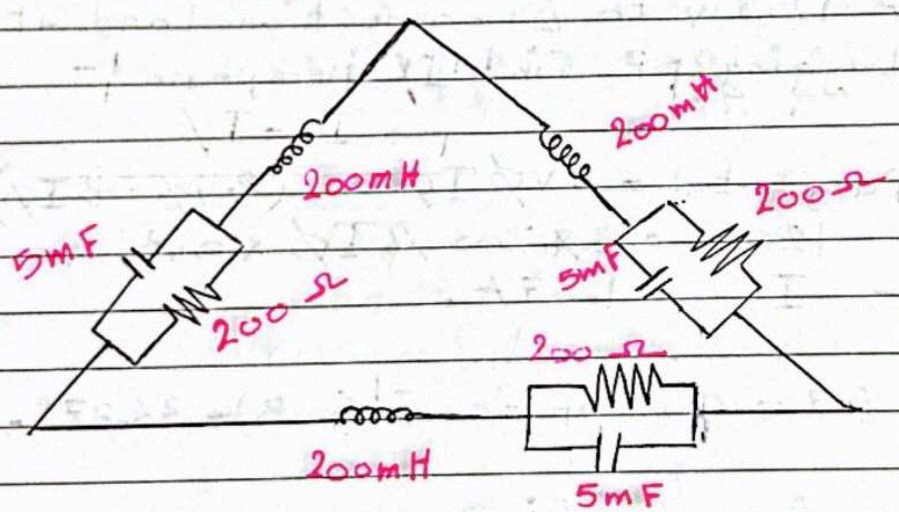
so :- $I_\phi = 1.67 \angle -36.87°$ A.

- In [Δ-connected] :-
$I_{Line} = \sqrt{3}\, I_\phi \angle -30°$.

$$I_{aA} = \sqrt{3}\, I_{AB} \angle -30^\circ$$
$$= \sqrt{3} \times 1.67 \angle -30^\circ - 36.87^\circ$$
$$= 2.9 \angle -66.87^\circ \text{ A}.$$
$$I_{bB} = 2.9 \angle -66.87^\circ - 120^\circ = 2.9 \angle -186.87^\circ \text{ A}.$$
$$I_{cC} = 2.9 \angle -66.87^\circ + 120^\circ = 2.9 \angle 53.13^\circ \text{ A}.$$

- $$Z\phi = \frac{V\phi}{I\phi} = \frac{300 \angle 0^\circ}{1.67 \angle -36.87^\circ} = 180 \angle -36.87^\circ \ \Omega.$$

(2) :- A [Δ- connected] phases, Load consists of 200 mH is series with parallel 5mF and 200 Ω, Vp = 200 V, w = 400 rad/s, Find Ip / IL / total Load power :-



- In [Δ- connected] :-
$$V\phi = V_L = 200 \text{ V}.$$

- $$Z_R = 200 \ \Omega.$$
$$Z_L = j\omega L = j\left[400 \times 200 \times 10^{-3}\right] = j80 \ \Omega.$$
$$Z_C = \frac{1}{j\omega c} = \frac{-j}{\left[400 \times 5 \times 10^{-3}\right]} = -j0.5 \ \Omega.$$

- $Z_{eq} = Z_L + [Z_C // Z_R]$
$= 79.5 \angle 89.99^\circ \ \Omega$.

- $I_\phi = \frac{V_\phi}{Z_{eq}} = \frac{200\angle 0^\circ}{79.5\angle 89.99^\circ} = 2.52 \angle -89.99^\circ$ A.

- $I_L = \sqrt{3}\, I_\phi \angle -30^\circ$
$= \sqrt{3} \times 2.52 \angle -30^\circ - 89.99^\circ$
$= 4.36 \angle -119.99^\circ$ A.

- $p_{total} = 3 V_\phi I_\phi\, pF$
$= 3 \times 200 \times 2.52 \times \cos(\text{zero}^\circ - - 89.99^\circ)$
$= 0.264$ W.

Q 1- A Δ Load requires a 15 KVA at 0.8 Lagging pF, +ve sequence, $V_{BC} = 180\angle 30^\circ$ vrms, $R_W = 0.75\ \Omega$, Find V_{bc} / total complex power generated by the source.

- $S = V_{BC} \times I_{BC}^*$
$I_{BC}^* = \frac{\frac{15K\angle 36.86^\circ}{3}}{180\angle 30^\circ}$ per phase
$I_{BC}^* = 27.78 \angle +6.86^\circ$
$I_{BC} = 27.78 \angle -6.86^\circ$

$\therefore S_{\text{per phase}} = \frac{15K}{3} \angle \cos^{-1} 0.8 = 5K \angle 36.86^\circ$ VA.

- $I_{Line} = \sqrt{3}\, I_\phi \angle -30^\circ$
$I_{bB} = \sqrt{3} \times 27.78 \angle -30^\circ - 6.86^\circ$
$= 48.12 \angle -36.86^\circ$ A.
$I_{cC} = 48.12 \angle -36.86^\circ - 120^\circ = 48.12 \angle -156.86^\circ$ A.

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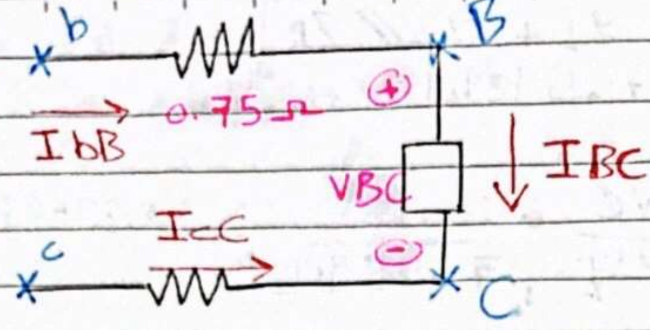


$$-V_{bc} + I_{bB} \times 0.75 + V_{BC} - I_{cC} \times 0.75 = \text{Zero}$$

$$V_{bc} = 0.75 \times 48.12 \angle{-36.86^\circ} + 0.75 \times 48.12 \angle{-156.86^\circ}$$

$$= 233 \angle{20.74^\circ} \text{ V.}$$

- $S_{total} = S_{in} = S_{\substack{Load \\ Loss}} + S_{output}$

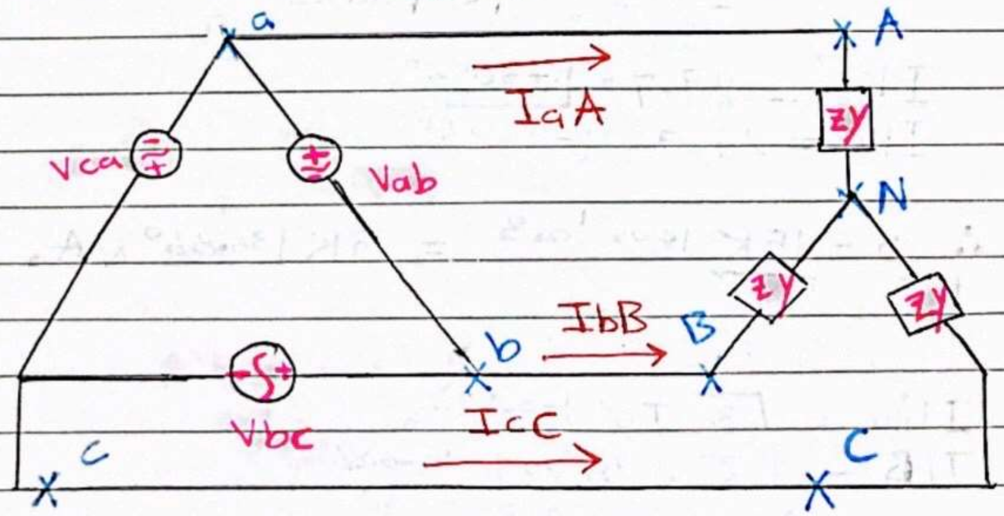
$$= 3 \times I^2 \times R_W + 15K \angle{\cos^{-1} pF}$$

$$= 3 \times 0.75 \times (48.12)^2 + 15K \angle{36.86^\circ}$$

$$= [17.2 + j9] \text{ KVA.}$$

4 Balanced [Δ-Y] connection :-

- Source ⟶ Δ-connected.
 Load ⟶ Y-connected.



- phase voltages :-

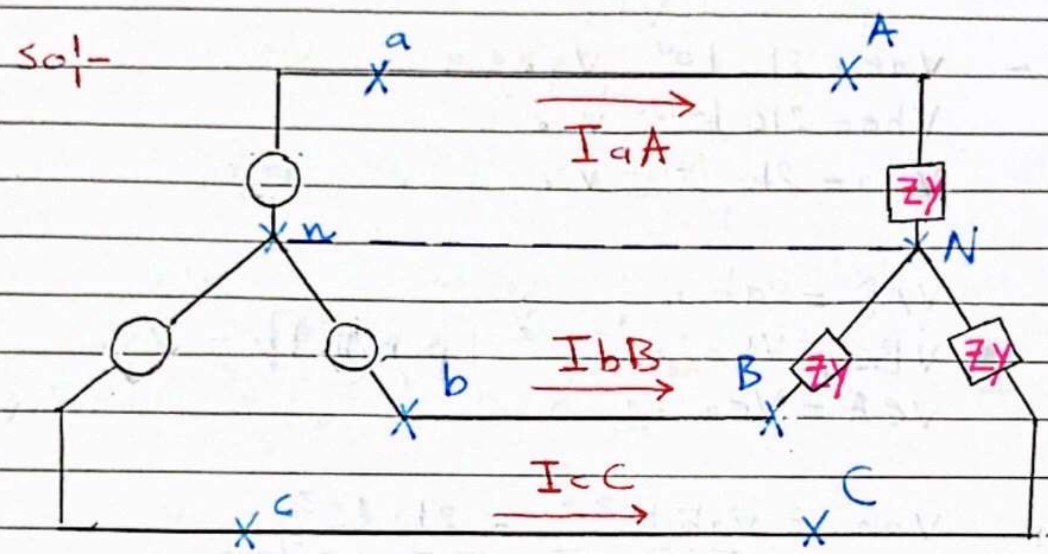
$V_{ab} = V_p \angle 0^\circ \ V$.

$V_{bc} = V_p \angle -120^\circ \ V$.

$V_{ca} = V_p \angle +120^\circ \ V$.

حتى أوجد قيمة الـ [Line currents] لازم احول جهة الـ source ، من [Δ-connected] إلى [Y-connected] :-

sol :-



- $V_{Line} = \sqrt{3}\ V_\phi \angle 30^\circ$

sol :- $V_{an} = \dfrac{V_{ab} \angle -30^\circ}{\sqrt{3}} \ V$.

$V_{bn} = V_{an} \angle -120^\circ \ V$.

$V_{cn} = V_{an} \angle +120^\circ \ V$.

- Line currents :-

$I_{aA} = \dfrac{V_{an}}{Z_Y} \ A$.

$I_{bB} = \dfrac{V_{bn}}{Z_Y} \ A$.

$I_{cC} = \dfrac{V_{cn}}{Z_Y} \ A$.

- $V_{AN} = I_{aA} \times Z_Y$
$V_{BN} = I_{bB} \times Z_Y$
$V_{CN} = I_{cC} \times Z_Y$

Q:- A [Y-connected] Load at $Z_Y = [40 + j25]$ is connected to [Δ-connected] source with $V_{ab} = 210 \angle 0^\circ$ V, Find voltages and currents :-

- $V_{ab} = 210 \angle 0^\circ$ V.
$V_{bc} = 210 \angle -120^\circ$ V.
$V_{ca} = 210 \angle +120^\circ$ V.

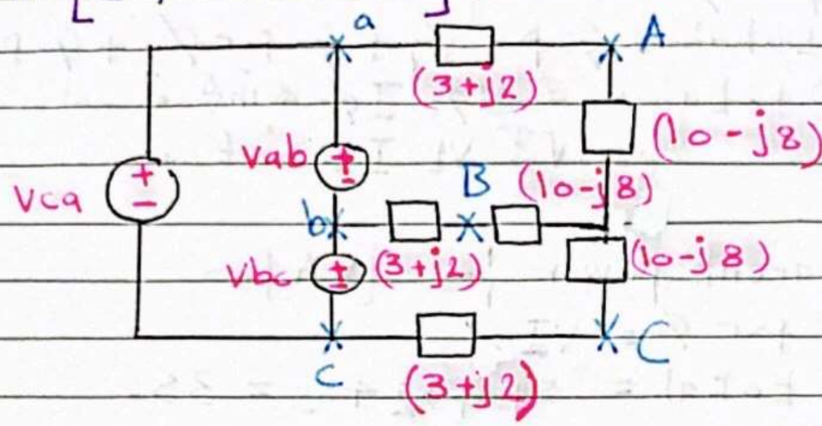
- $V_{AB} = V_{ab}$.
$V_{BC} = V_{bc}$.   [parallel]
$V_{CA} = V_{ca}$.

- $$V_{an} = \frac{V_{ab} \angle -30^\circ}{\sqrt{3}} = \frac{210 \angle -30^\circ}{\sqrt{3}}$$
$= 121.24 \angle -30^\circ$ V.
$V_{bn} = 121.24 \angle -30^\circ - 120^\circ = 121.24 \angle -150^\circ$ V.
$V_{cn} = 121.24 \angle -30^\circ + 120^\circ = 121.24 \angle 90^\circ$ V.

- $$I_{aA} = \frac{V_{an}}{Z_Y} = \frac{121.24 \angle -30^\circ}{[40 + j25]} = 2.57 \angle -62^\circ \text{ A}.$$
$I_{bB} = 2.57 \angle -62^\circ - 120^\circ = 2.57 \angle -182^\circ$ A.
$I_{cC} = 2.57 \angle -62^\circ + 120^\circ = 2.57 \angle 58^\circ$ A.

- $V_{AN} = I_{aA} \times Z_Y = 2.57 \angle -62^\circ \times [40 + j25]$
$= 121.2 \angle -30^\circ$ V.
$V_{BN} = 121.2 \angle -30^\circ - 120^\circ = 121.2 \angle -150^\circ$ V.
$V_{CN} = 121.2 \angle -30^\circ + 120^\circ = 121.2 \angle 90^\circ$ V.

① :- IF $V_{ab} = 440 \angle 10°$, $V_{bc} = 440 \angle 250°$, $V_{ca} = 440 \angle 130°$ in [Δ-Y connected] , Find the currents :-



– $V_{an} = \dfrac{V_{ab} \angle -30°}{\sqrt{3}} = \dfrac{440 \angle 10°-30°}{\sqrt{3}} = 254.03 \angle -20°$ V.

$V_{bn} = 254.03 \angle -20°-120° = 254.03 \angle -140°$ V.

$V_{cn} = 254.03 \angle -20°+120° = 254.03 \angle 100°$ V.

– $Z_Y = Z_{Line} + Z_{Load}$

$= [3+j2] + [10-j8] = [13-j6]\ \Omega$

– $I_a = \dfrac{V_{an}}{Z_Y} = \dfrac{254.03 \angle -20°}{[13-j6]} = 17.74 \angle 4.78°$ A.

$I_b = 17.74 \angle 4.78°-120° = 17.74 \angle -115.22°$ A.

$I_c = 17.74 \angle 4.78°+120° = 17.74 \angle 124.78°$ A.

– power in a balanced system :-

– Active power :- [W]

$P_{per\,\phi} = V_P I_P \cos\theta$.

$P_{total} = P_{per\,\phi_1} + P_{per\,\phi_2} + P_{per\,\phi_3} = 3P$.

so :- $P_{total} = 3 V_\phi I_\phi \cos\theta$.

$= \sqrt{3}\, V_L I_L \cos\theta$.

- Reactive power :- [VAR]

Q per ϕ = $VI\sin\theta$.

$Q_{total} = Q \text{ per } \phi_1 + Q \text{ per } \phi_2 + Q \text{ per } \phi_3 = 3Q$.

so :- $Q_{total} = 3 V_\phi I_\phi \sin\theta$.

$= \sqrt{3} V_L I_L \sin\theta$.

- Apparent power :- [VA]

S per ϕ = VI.

$S_{total} = S_1 + S_2 + S_3 = 3S$.

$S_{total} = 3 V_\phi I_\phi$.

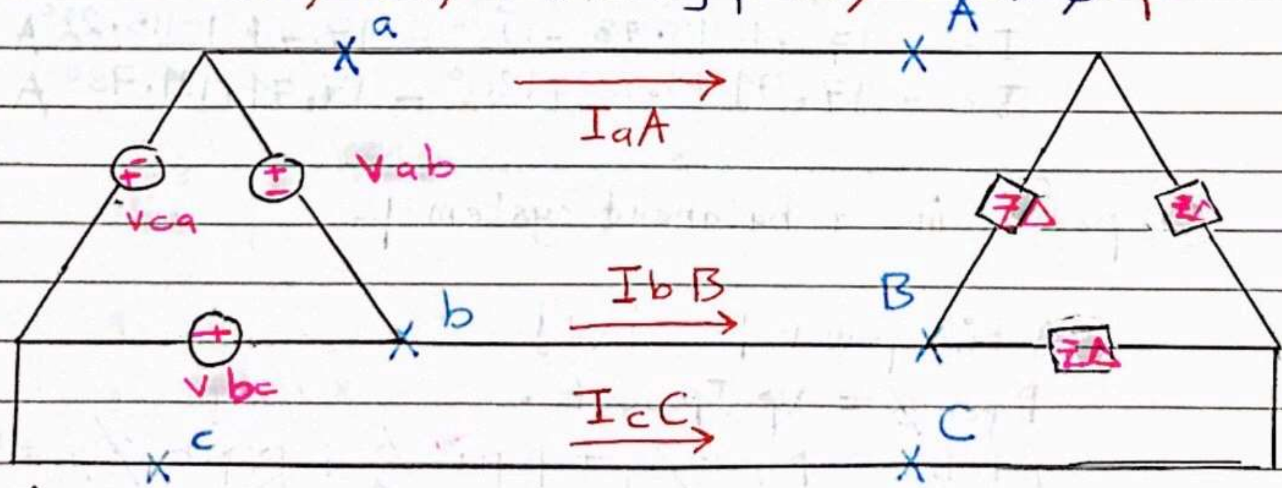
$= \sqrt{3} V_L I_L$.

- Complex power :- [VA]

$\tilde{S} \text{ per } \phi = \tilde{V}_\phi \tilde{I}_\phi^{*} = P_\phi + jQ_\phi$.

$\tilde{S}_{total} = 3\tilde{V}_\phi \tilde{I}_\phi^{*} = \dfrac{3 V_\phi^2}{Z^*} = 3 I_\phi^2 \times Z$.

Q :- A [Δ-Δ connected] with $V_{ab} = 440\angle 0^\circ$, $Z_L = [10 + j15]\ \Omega$, find Line currents / V_{CA} / I_{ca} / total avg power / total Q :-



- phase currents :-

$$I_{AB} = \frac{440\angle 0^\circ}{[10+j15]} = 31.11\angle -45^\circ \text{ A}.$$

$$I_{BC} = 31.11\angle -45^\circ-120^\circ = 31.11\angle -165^\circ \text{ A}.$$

$$I_{CA} = 31.11\angle -45^\circ+120^\circ = 31.11\angle 75^\circ \text{ A}.$$

— Line currents !—

$$I_{aA} = \sqrt{3}\, I_{AB}\angle -30^\circ = \sqrt{3} \times 31.11\angle -45^\circ-30^\circ$$
$$= 53.88\angle -75^\circ \text{ A}.$$

$$I_{bB} = 53.88\angle -75^\circ-120^\circ = 53.88\angle -195^\circ \text{ A}$$

$$I_{cC} = 53.88\angle -75^\circ+120^\circ = 53.88\angle 45^\circ \text{ A}$$

— VCA ?!

$$V_{ab} = V_{AB} = 440\angle 0^\circ \text{ V}.$$

$$V_{bc} = V_{BC} = 440\angle 0^\circ-120^\circ = 440\angle -120^\circ \text{ V}.$$

$$V_{ca} = V_{CA} = 440\angle 0^\circ+120^\circ = 440\angle 120^\circ \text{ V}.$$

— Ica ?!

$$I_{ca} = I_{CA} = 31.11\angle +75^\circ \text{ A}.$$

— total avg power ?!

$$P_{avg} = 3 V_\phi I_\phi \cos\theta$$
$$= 3 \times 440 \times 31.11 \cos(0^\circ - -45^\circ)$$
$$= 29.03 \text{ KW}$$

— total reactive power ?!

$$Q = 3 V_\phi I_\phi \sin\theta = 3 \times 440 \times 31.11 \times \sin 45^\circ$$
$$= 29.03 \text{ KVAR}.$$

كُن أفضل نسخة من نفسك

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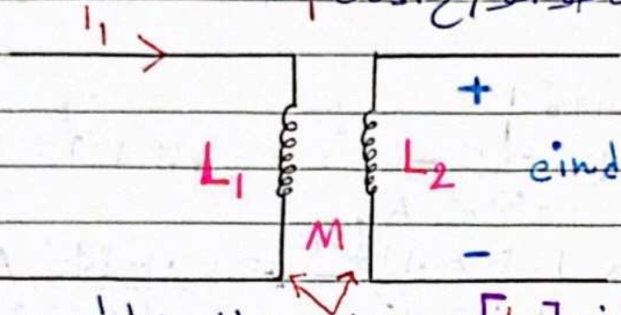
CH :- "Magnetically coupled circuits" :-

هنا يعني لما يكون عندي [2 inductors] أو أكثر بدارة واحدة أو بدارتين منفصلتين ، كما هو موضح أدناه :-



عندما يمر تيار كهربائي [i_1] في [L_1] ، يتولد مجال مغناطيسي [Flux] في [L_1] وسيؤثر على [L_2] والذي يؤدي بدوره إلى مرور [i_2] في [L_2] وينتج عنه [eind] .

- M :- Mutual inductance . مشتركة بين [2 inductors]

$$M_{12} = M_{21} = M \quad \dots (1)$$

eind :- [e induced] → voltage.

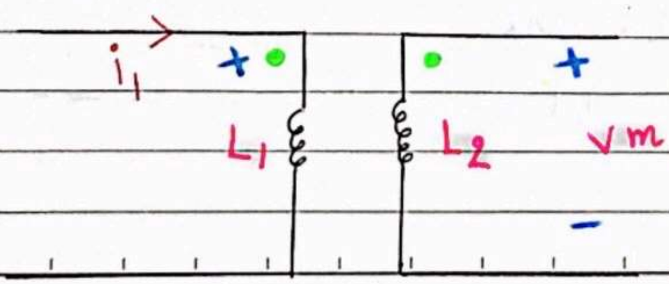
$$e_{ind} = v_m = M \frac{di}{dt} \quad \dots (2)$$

∴ Note :-

- Mutual inductance :- describes the voltage induced at the end of the coil due to a magnetic field generated by the source.

- Dot convention :-
to find the direction of vm.

[1]



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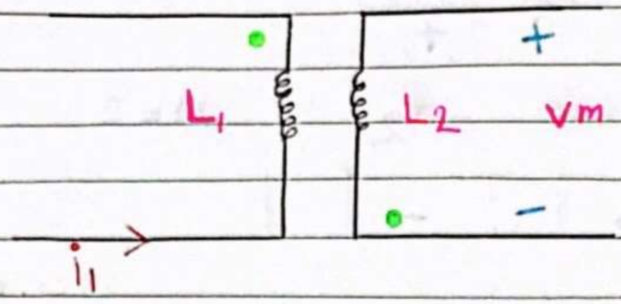

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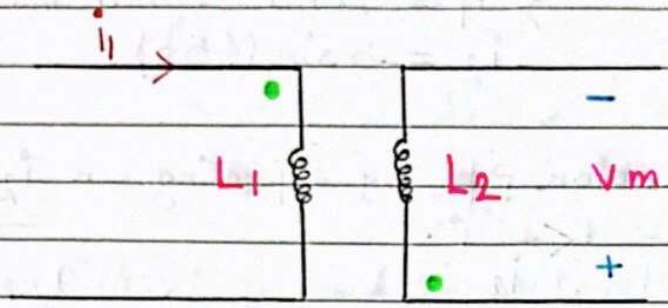

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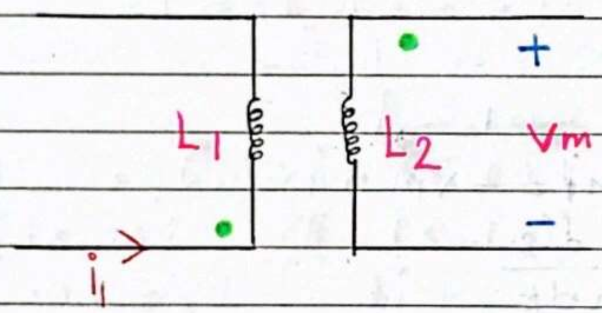
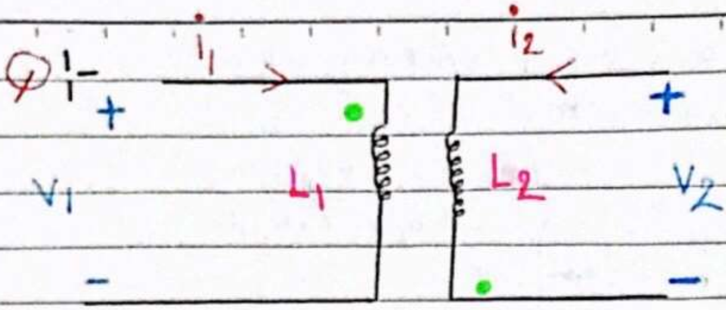


لكي يتم تحديد الـ [direction of vm] نتتبع اتجاه دخول التيار في [L_1] في حال دخل بالـ [dot] نبحث عن [dot] الموجودة في الدارة الثانية ونضع عندها (+) ، وفي حال دخل بالـ [undot] نبحث عن [undot] الموجودة في الدارة الثانية ونضع عندها (+).

- If the current enters from dotted end, eind (+) at dotted end.
- If the current enters from undotted end, eind (+) at undotted end.

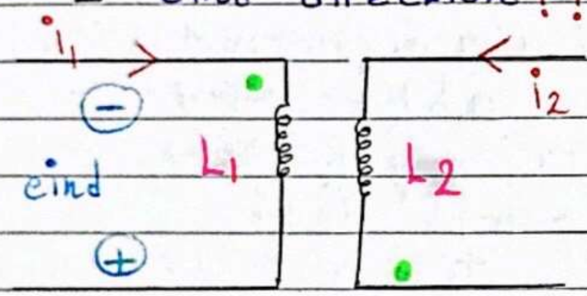
Q) :-



$M = 2$

1) Find :- V_1 if $\longrightarrow$ $i_1 = \text{Zero}$. [self induced] (o.c)
$i_2 = 5\sin(45t)$.

- eind direction ?! by depending on $\underline{\underline{i_2}}$



$$V_1 = -\,eind = -\,Vm$$
$$V_1 = -M\frac{di_2}{dt}$$
$$V_1 = -2 \times \frac{d}{dt}(5\sin 45t)$$
$$V_1 = -2 \times 5 \times 45 \times \cos 45t)$$
$$V_1 = -450\cos(45t)\ V$$

2) Find :- V_2 if $\longrightarrow$ $i_1 = -8e^{-t}$.
$i_2 = \text{Zero}$. [self induced] (o.c)

- eind direction ?! by depending on $\underline{\underline{i_1}}$

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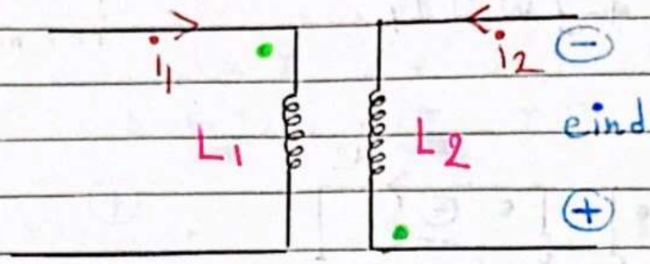


$$V_2 = -e_{ind} = -V_m$$

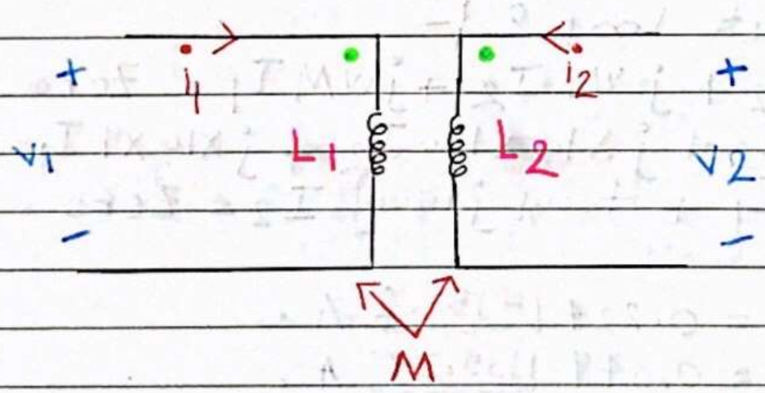
$$V_2 = -M\frac{di_1}{dt}$$

$$V_2 = -2\times\frac{d}{dt}\left(-8e^{-t}\right)$$

$$V_2 = -2\times -8\times -1\times e^{-t}$$

$$V_2 = -16e^{-t}\ V.$$

– combined mutual and self inductance :-



– $V_1 = Z_L \times I_1 + V_m$

$$V_1 = jwLI_1 + M\frac{di_2}{dt}$$

so:- $V_1 = jwLI_1 + jwMI_2$ ... (1) phasor form

– $V_2 = ZL \times I_2 + V_m$

$$V_2 = jwLI_2 + M\frac{di_1}{dt}$$

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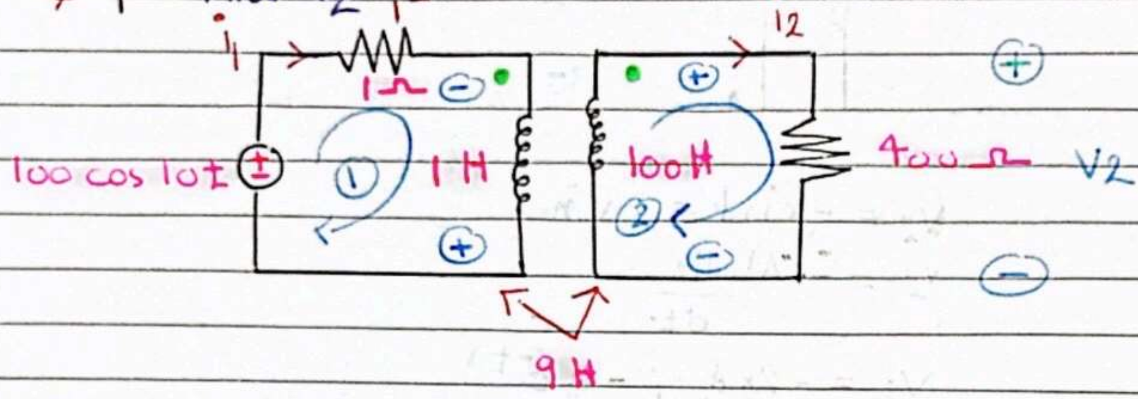
Sol :- $V_2 = jwLI_2 + jwMI_1$ ... (2) Phasor Form

Q :- Find V_2 :-



- KVL at Loop 1 :-

$$-10\angle 0^\circ + 1 \times I_1 + jwL\, I_1 - jwM\, I_2 = \text{Zero}$$

$$-10\angle 0^\circ + I_1 + j \times 10\, I_1 - j \times 10 \times 9\, I_2 = \text{Zero}$$

$$[1 + j10]\, I_1 + -j90\, I_2 = 10 \quad \dots (1)$$

- KVL at Loop 2 :-

$$400\, I_2 + jwL\, I_2 + jwM\, I_1 = \text{Zero}$$

$$400\, I_2 + j \times 10 \times 100\, I_2 + j \times 10 \times 9\, I_1 = \text{Zero}$$

$$j90\, I_1 + [400 + j1000]\, I_2 = \text{Zero} \quad \dots (2)$$

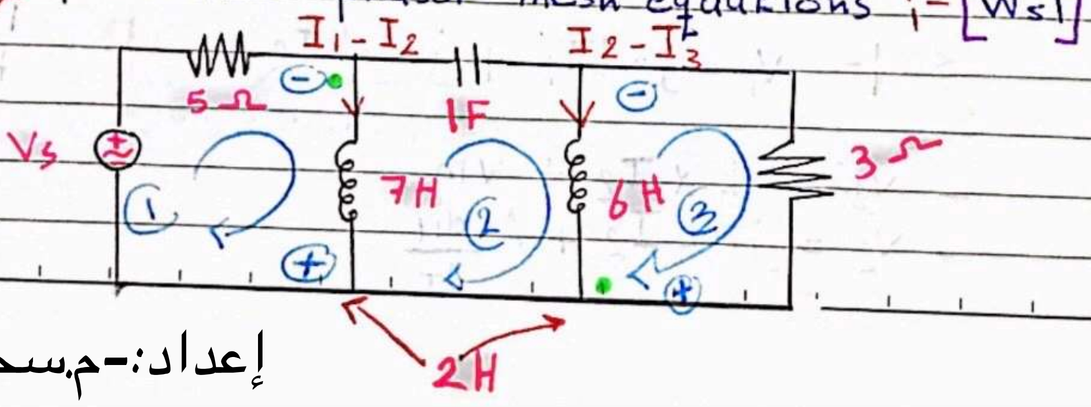
by Carmer's rule

$$I_1 = 0.224 \angle -150.2^\circ \text{ A.}$$

$$I_2 = 0.049 \angle 105.77^\circ \text{ A.}$$

- $V_2 = RI_2 = 400 \times 0.049 \angle 105.77^\circ$
$= 19.6 \angle 105.77^\circ$ V.

Q :- Write phasor mesh equations :- [Ws1]



- KVL at Loop 1 :-

$$-V_S + 5I_1 + 7jw[I_1 - I_2] - j2w[I_2 - I_3] = \text{Zero}$$

$$-V_S + 5I_1 + j7[I_1 - I_2] - j2[I_2 - I_3] = \text{zero} \quad \dots (1)$$

- KVL at Loop 3 :-

$$3I_3 + 6jw[I_3 - I_2] + 2jw[I_1 - I_2] = \text{zero}$$

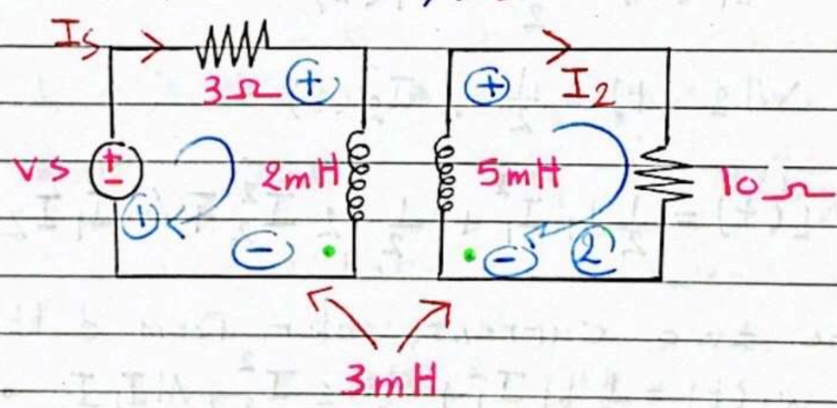
$$3I_3 + j6[I_3 - I_2] + j2[I_1 - I_2] = \text{zero} \quad \dots (2)$$

- KVL at Loop 2 :-

$$-jwI_2 + 6jw[I_2 - I_3] - 7jw[I_1 - I_2] + 2jw[I_2 - I_3] - 2jw[I_1 - I_2] = \text{zero}$$

$$-jI_2 + j6[I_2 - I_3] - j7[I_1 - I_2] + j2[I_2 - I_3] - j2[I_1 - I_2] = \text{zero} \quad \dots (3)$$

(4) :- If $w = 5000$ rad/s, write the equations :-



- KVL at Loop 1 :-

$$-V_S + 3I_S + j2m \times 5000 I_S - j3m \times 5000 I_2 = \text{Zero}$$

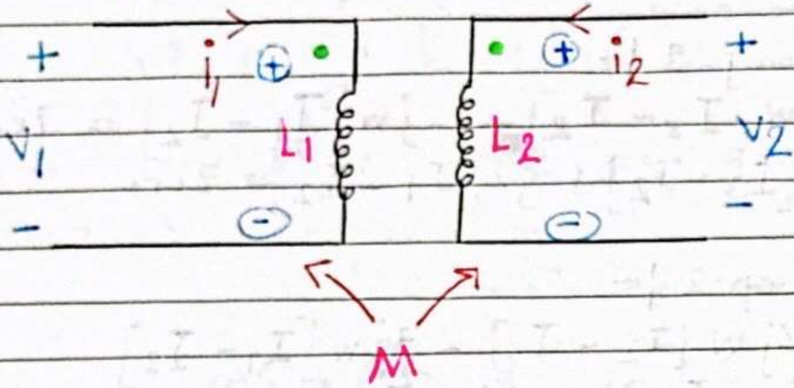
$$-V_S + 3I_S + j10I_S - j15I_2 = \text{zero} \quad \dots (1)$$

- KVL at Loop 2 :-

$$10I_2 + j5m \times 5000 I_2 - j3m \times 5000 I_S = \text{zero}$$

$$10I_2 + j10I_2 - j15I_S = \text{zero} \quad \dots (2)$$

- Energy consideration :-
stored energy for inductive loads [inductors] or [coils].



$$V_1 = j\omega L_1 I_1 + j\omega M I_2$$
$$V_2 = j\omega L_2 I_2 + j\omega M I_1$$

so :- $W_{L_1}(t) = \frac{1}{2} L_1 I_1^2(t)$

$W_{L_2}(t) = \frac{1}{2} L_2 I_2^2(t)$

so :- $W_L(t) = \frac{1}{2} L_1 I_1^2 + \frac{1}{2} L_2 I_2^2 \mp M I_1 I_2$

- If the two currents enter from dotted area, so :- $W_L(t) = \frac{1}{2} L_1 I_1^2 + \frac{1}{2} L_2 I_2^2 + M I_1 I_2$.

- If one current enters from dotted area and the other current enters from undotted area, so :- $W_L(t) = \frac{1}{2} L_1 I_1^2 + \frac{1}{2} L_2 I_2^2 - M I_1 I_2$.

∴ Note :-
$M = K\sqrt{L_1 L_2}$, K: coupling coefficent [given]

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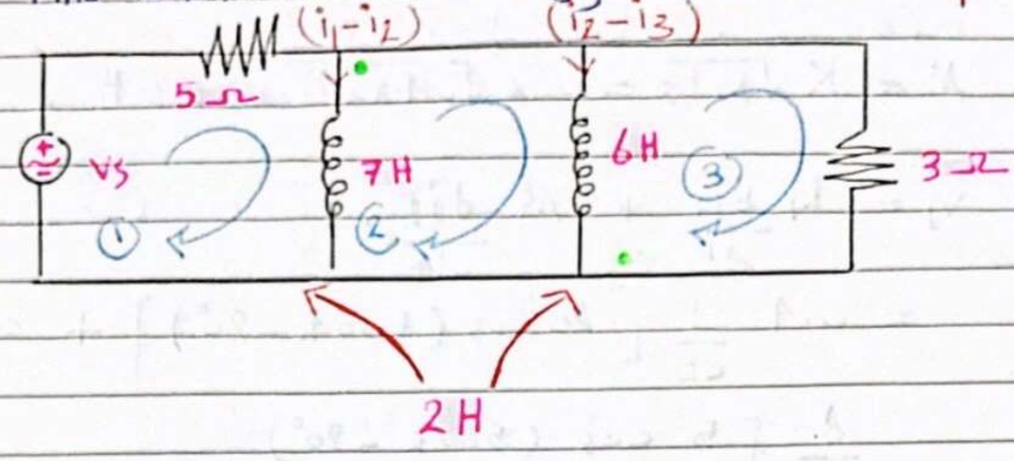
Q :- Find total stored energy in inductors :-



$$w_L(t) = \frac{1}{2} L_1 I_1^2 + \frac{1}{2} L_2 I^2 \mp M I_1 I_2$$

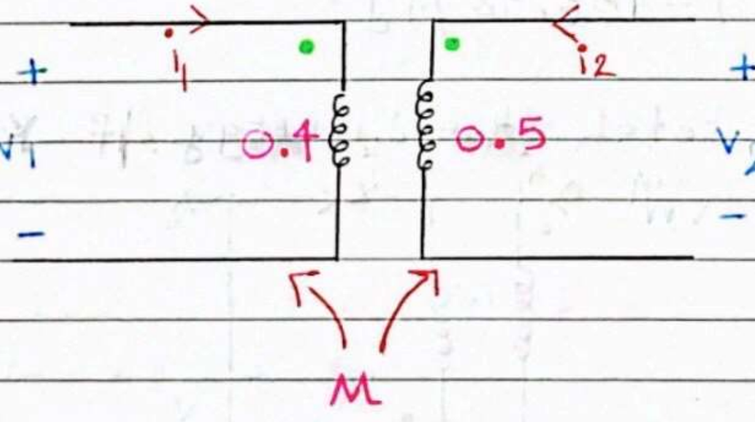
sol :- $w_L(t) = \frac{1}{2}\times 7\times[i_1-i_2]^2 + \frac{1}{2}\times 6\times[i_2-i_3]^2$

$- 2\times[i_1-i_2]\times[i_2-i_3]$ joul.

∴ Note :- $M = K\sqrt{L_1 L_2}$, $[0<K<1]$

كلما كانت قيمة [K] أقرب إلى [1] ، كلما كانت [2 inductors] أقرب لبعض في المسافة.

Q :- Find i_2 / v_1 / total stored energy at t = zero, if $K=0.6$, $i_1 = 4 i_2 = 20\cos(500t-20°)$ mA :-



$$- \quad i_2 = \frac{i_1}{4} = \frac{20}{4}\cos(500t-20°) = 5\cos(500t-20°).$$

sol:- $i_2(0) = 4.698\ mA$.

- $M = K\sqrt{L_1 L_2} = 0.6\sqrt{0.4\times 2.5} = 0.6\ H$.

- $V_1 = L_1 \frac{di_1}{dt} + M\frac{di_2}{dt}$

time domain

$= 0.4\ \frac{d}{dt}\left[20\cos(500t-20^\circ)\right] + 0.6\ \frac{d}{dt}\left[5\cos(500t-20^\circ)\right]$

$= -0.4\times 20\times 500\ \sin(500t-20^\circ) + -0.6\times 5\times 500\ \sin(500t-20^\circ)$

$= -4000\sin(500t-20^\circ) - 1500\sin(500t-20^\circ)$

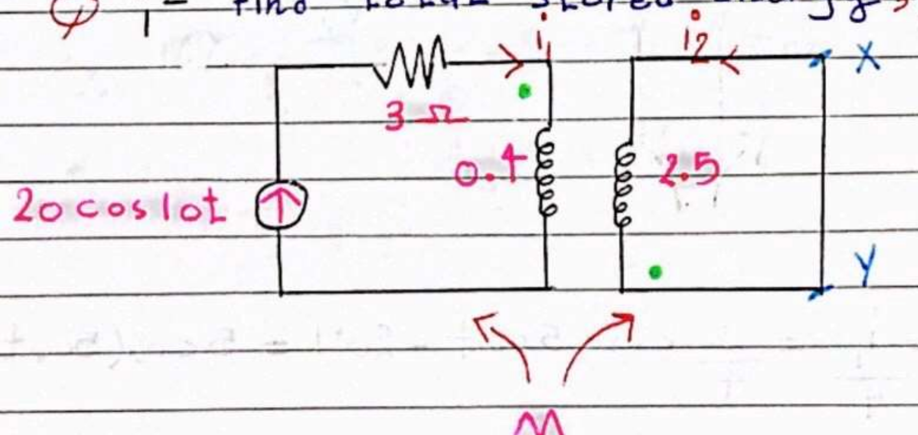
sol:- $V_1(0) = 1.88\ V$.

- $W_L(t) = \frac{1}{2}L_1 I_1^2 + \frac{1}{2}L_2 I_2^2 \mp M I_1 I_2$

$W_L(t) = \frac{1}{2}\times 0.4\times\left[20\cos(500t-20^\circ)\right]^2 + \frac{1}{2}\times 2.5\times\left[5\cos(500t-20^\circ)\right]^2 + 0.6 \times\left[20\cos(500t-20^\circ)\right]\times\left[5\cos(500t-20^\circ)\right]$

sol:- $W_L(0) = 150.98\ MJ$.

Q:- Find total stored energy, if $K = 0.6$:-



- if X-y open at $t=0$:-

$$M = K\sqrt{L_1 L_2} = 0.6\sqrt{0.4\times 2.5} = 0.6H.$$

$$I_2 = \text{zero}.$$

$$W_L(t) = \frac{1}{2}L_1 I_1^2 + \cancel{\frac{1}{2}L_2 I_2^2} \cancel{\mp M I_1 I_2}$$

$$WL(t) = \frac{1}{2}\times 0.4\times\left[2\times\cos(10t)\right]^2$$

so:- $W_L(0) = \frac{1}{2}\times 0.4\times\left[2\times\cos(\text{zero})\right]^2 = 0.8J.$

- if X-y short at $t=0$:-

$$V_m = M\frac{di_1}{dt} = 0.6\times\frac{d}{dt}\left[2\cos 10t\right]$$

$$= -0.6\times 2\sin(10t)\times 10$$

$$= -12\sin(10t)\,V.$$

$$i_2 = \frac{1}{L_2}\int V_m\,dt$$

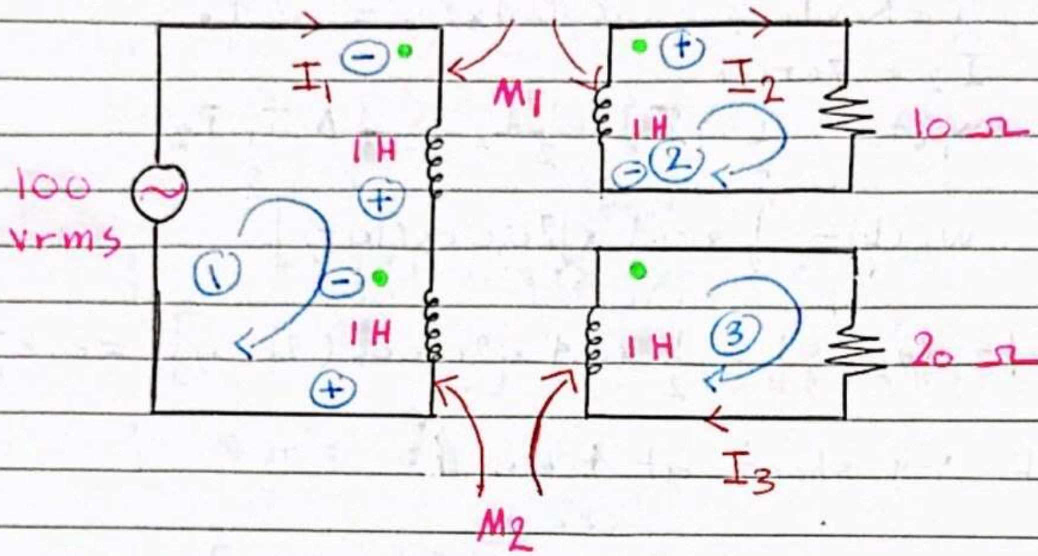
$$= \frac{1}{2.5}\int -12\sin(10t)\,dt = 0.48\cos(10t)A.$$

$$WL(t) = \frac{1}{2}L_1 I_1^2 + \frac{1}{2}L_2 I_2^2 \mp M I_1 I_2$$

$$= \frac{1}{2}\times 0.4\times\left[2\cos(10t)\right]^2 + \frac{1}{2}\times 2.5\times\left[0.48\cos(10t)\right]^2 - 0.6\times\left[2\cos(10t)\right]\left[0.48\cos(10t)\right]$$

so:- $W_L(0) = 0.512J.$

Q :- Find the phasor equations , if $w = 100 (rad/s)$ / $K_1 = 0.5$ / $K_2 = 0.2$:-



- $M_1 = K_1 \sqrt{L_1 L_2} = 0.5 \sqrt{1 \times 1} = 0.5$.
  $M_2 = K_2 \sqrt{L_1 L_2} = 0.2 \sqrt{1 \times 1} = 0.2$.

- KVL at Loop 1 :-

$$-100 + j100 I_1 + j100 I_1 + -j100 \times 0.5 I_2 - j100 \times 0.2 I_3 = zero$$

$$-100 + j100 I_1 + j100 I_1 + -j50 I_2 - j20 I_3 = zero \quad \dots (1)$$

- KVL at Loop 2 :-

$$10 I_2 + j100 I_2 + -j100 \times 0.5 I_1 = zero$$

$$10 I_2 + j100 I_2 - j50 I_1 = zero \quad \dots (2)$$

- KVL at Loop 3 :-

$$20 I_3 + j100 I_3 - j100 \times 0.2 I_1 = zero$$

$$20 I_3 + j100 I_3 - j20 I_1 = zero \quad \dots (3)$$

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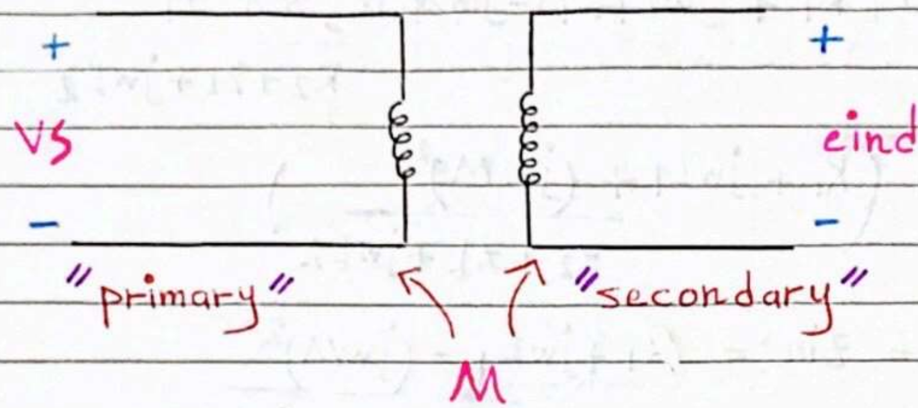
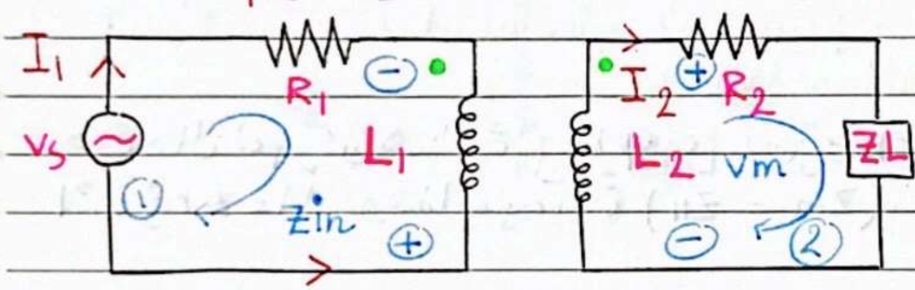
- Linear transform :-



∴ Note :-

عندما يطلب حساب [Zin] غالباً يتم حسابها من جهة الـ [primary]
إلا إذا حدد هو غير ذلك ، وفيما يلي اشتقاق قانون [Zin] :-



- $Z_{in} = \dfrac{V_s}{I_1}$.

- KVL at Loop 1 :-

$$-V_s + I_1 R_1 + jwL_1 I_1 - jwMI_2 = \text{Zero}$$

$$V_s = I_1 R_1 + jwL_1 I_1 - jwMI_2 \quad \dots (1)$$

- KVL at loop 2 :-

$$I_2 R_2 + Z_L I_2 + jwL_2 I_2 - jwMI_1 = \text{zero} \quad \dots (2)$$

- From equation (2) :-

$$I_2 = \frac{jwMI_1}{R_2 + Z_L + jwL_2}$$

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- نعوض I_2 في equation(1) :-

$$V_S = I_1 R_1 + jwL_1 I_1 - jwM \times \frac{jwM I_1}{R_2 + Z_L + jwL_2}$$

$$V_S = I_1 \left(R_1 + jwL_1 - \frac{(jwM)^2}{R_2 + Z_L + jwL_2} \right)$$

so :- $$\frac{V_S}{I_1} = Z_{in} = \underbrace{R_1 + jwL_1}_{Z_{11}} - \frac{(jwM)^2}{\underbrace{R_2 + Z_L + jwL_2}_{Z_{22}}}$$

so :- $$\left[Z_{in} = Z_{11} + \frac{w^2 M^2}{Z_{22}} \right]$$

∴ Note :-

في حال لم يكن هنالك [coupling] بين [2inductors] وهنا يعني

أنّ [M = zero] وهنا يعني أنّ $(Z_{in} = Z_{11})$.

- $$Z_{in} = Z_{11} + \frac{M^2 w^2}{Z_{22}}$$.

Z_{11} :- primary impedence.

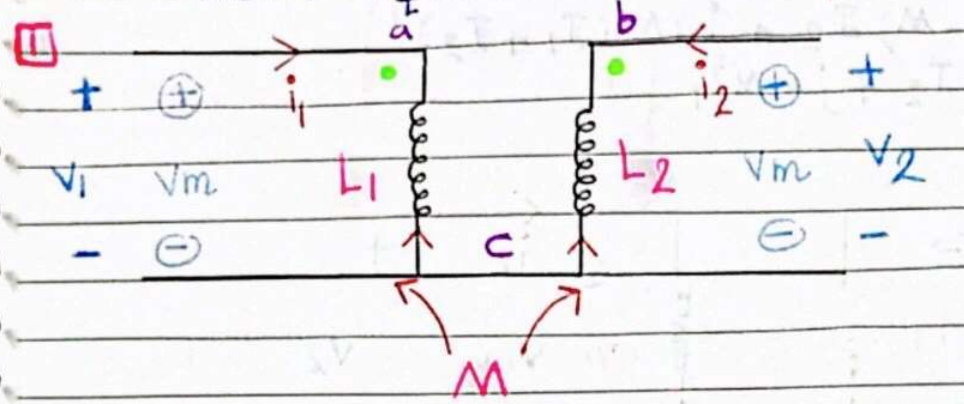
Z_{22} :- secondary impedence.

$\frac{w^2 M^2}{Z_{22}}$:- reflected input .

∴ Note :-

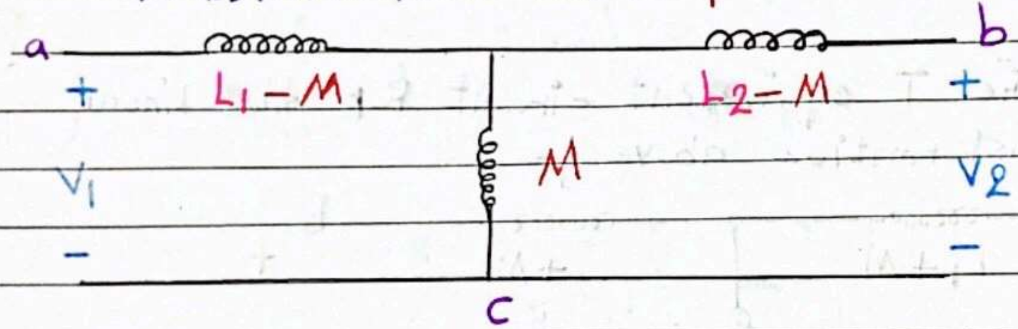
اشتقاق قانون [Zin] ليس للحفظ .

- The T equivalent circuit :-



[Figure 1]

sol:- The T equivalent circuit for the linear transformation above :-



[Figure 2]

- هنا في حالة دخل التيار المتفرع من (c) في الرسمة الأولى قبل التحويل إلى الـ [T-equivalent] في الـ (primary) والـ (secondary) في [dotted area] للجهتين أو في الـ [undotted area] للجهتين أيضاً.

- لإثبات أن [V_1/V_2] في الرسمة الأولى مساويين لـ [V_1/V_2] في الرسمة الثانية :-

- For the circuit in [Figure 1] :-

$$V_1 = jwL_1 I_1 + jwM I_2$$
$$V_2 = jwL_2 I_2 + jwM I_1$$

- For the circuit in [Figure 2] :-

$$V_1 = jw(L_1 - M) I_1 + jwM (I_1 + I_2)$$

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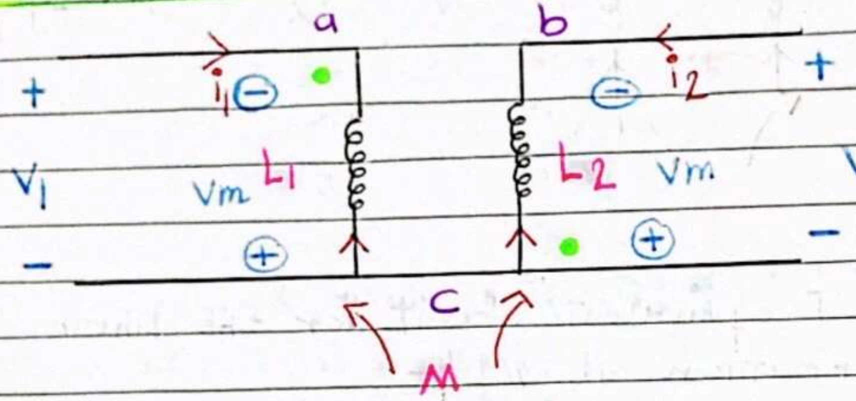
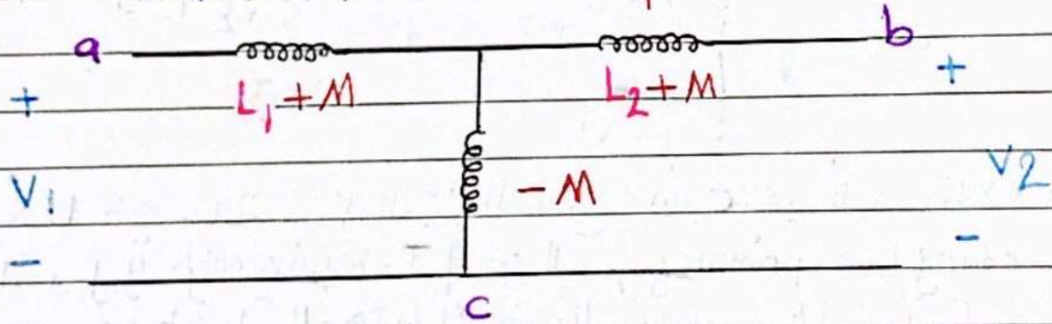
$$V_1 = jwL_1 I_1 + jwMI_2$$
$$V_2 = jw(L_2 - M) I_2 + jwM(I_1 + I_2)$$
$$V_2 = jwL_2 I_2 + jwMI_1$$

2

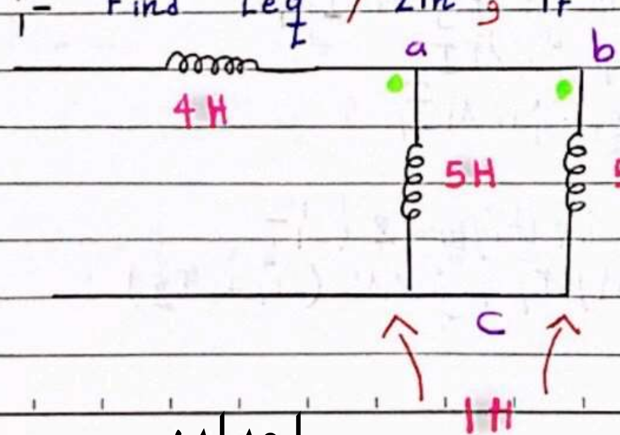


sol:- The T equivalent circuit for the linear transformation above :-

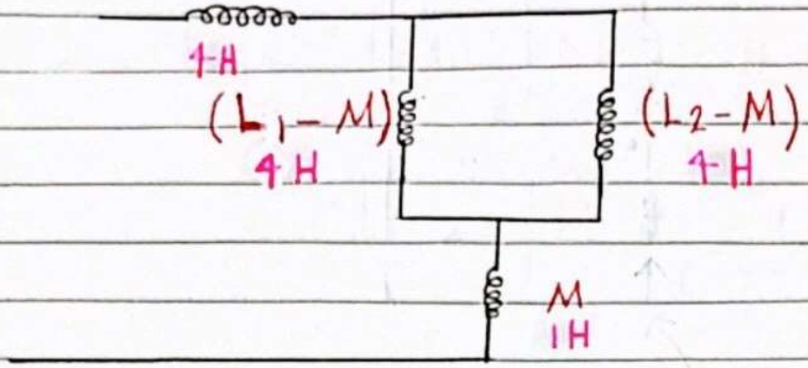


- هنا في حالة دخل التيار المتفرع من (c) في الرسمة الأولى قبل التحويل إلى [T equivalent] في الـ (primary) والـ (secondary) أخذهما في [dotted area] والآخر في [undotted area].

Q :- Find L_{eq} / Z_{in} , if $w = 200$ rad/s :-



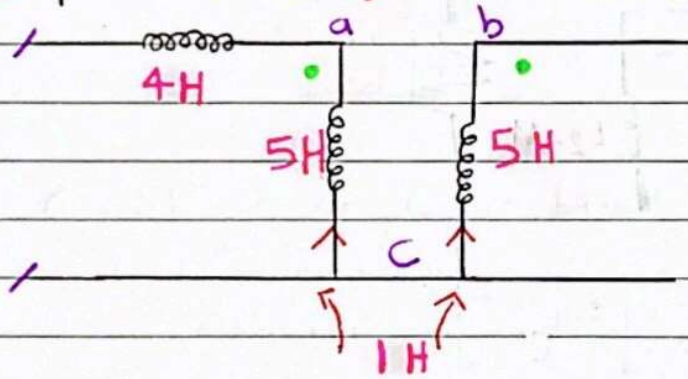
- The T-equivalent circuit :-



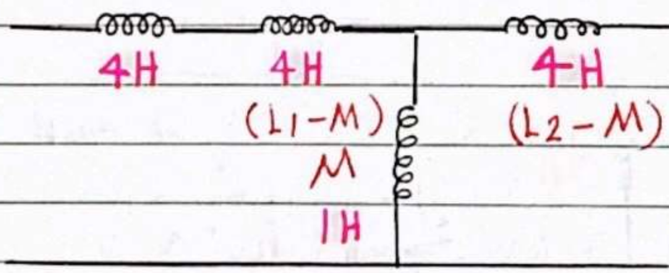
- $L_{eq} = 4 + [4 // 4] + 1 = 4 + 2 + 1 = 7H$.

- $Z_{in} = j\omega L_{eq} = j \times 200 \times 7 = j1400\ \Omega$.

Q :- Find Z_{in}, if $w = 200$ rad/s :-



- The T-equivalent circuit :-

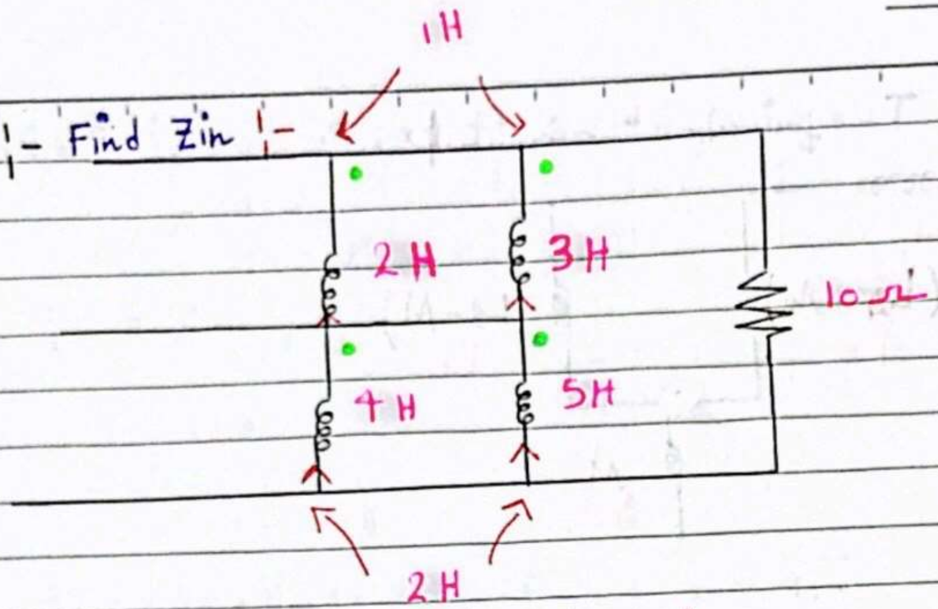


- $L_{eq} = [(4+4) // 4] + 1 = 3.66\ H$.

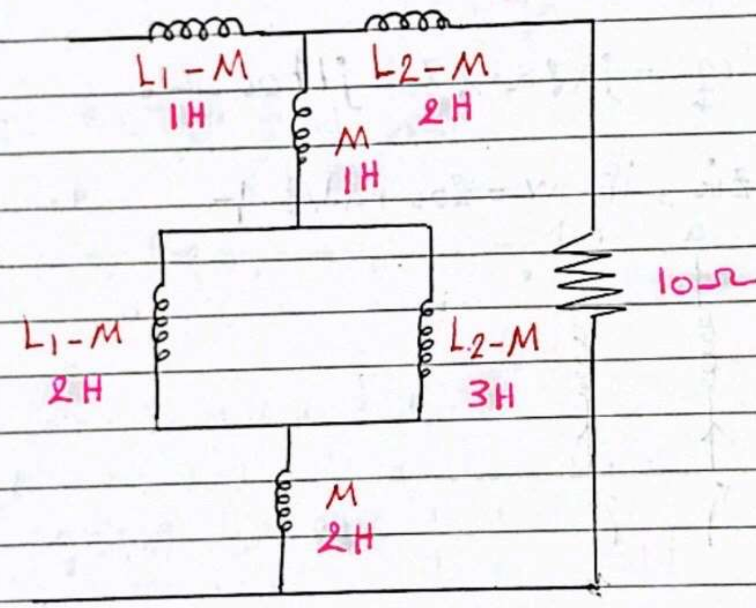
- $Z_{in} = j\omega L_{eq} = j \times 200 \times 3.66 = j732\ \Omega$.

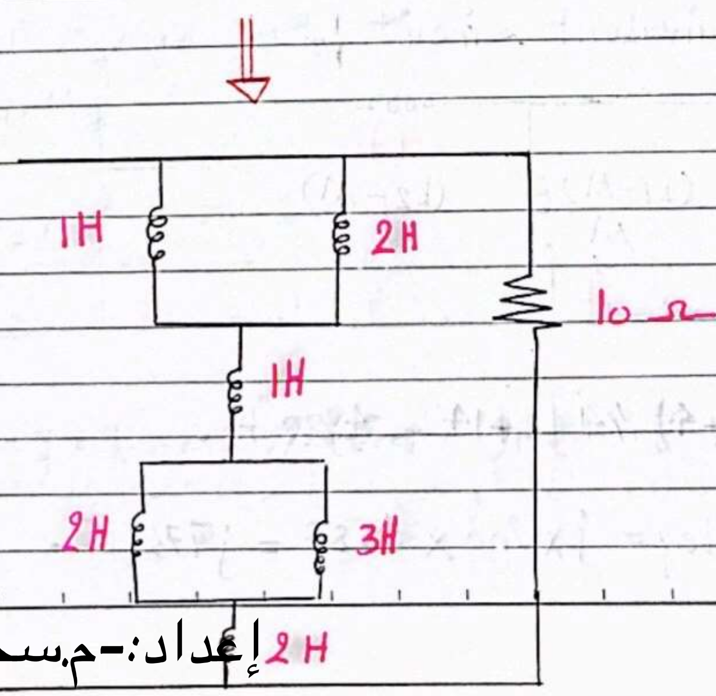
إعداد:-م.سجى البزايعه

Q 1- Find Zin :-



- The T-equivalent circuit :-





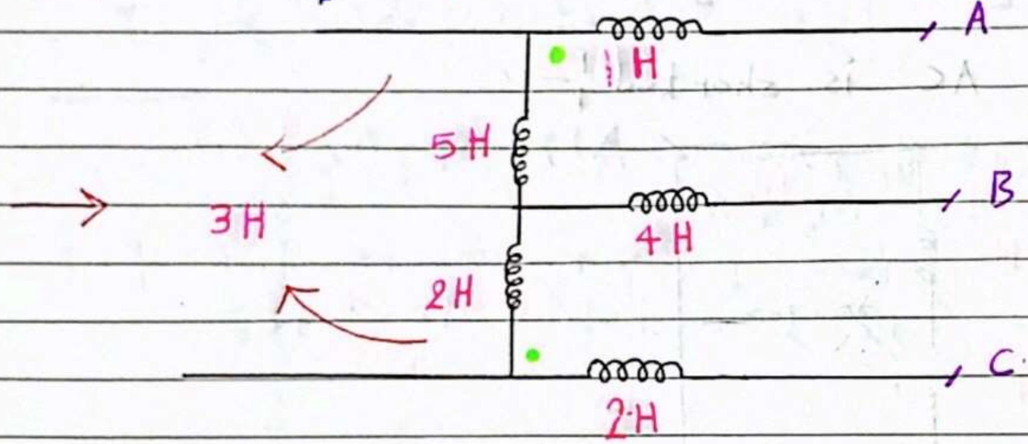
- $L_{eq} = (1/\!/2) + 1 + (2/\!/3) + 2 = 4.86\,H$.

- $Z_{in} = j\omega L_{eq} /\!/ 10$ | $\omega = 200$ rad/s

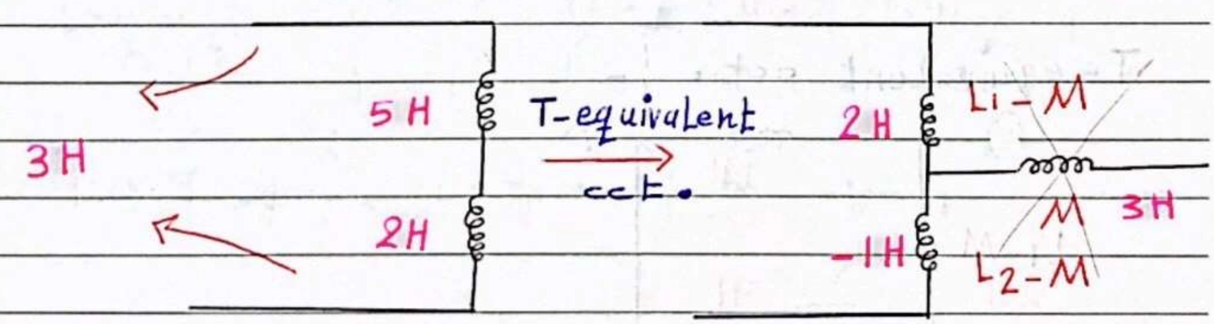
$= j(200 \times 4.86) /\!/ 10$

$= j972 /\!/ 10 = \dfrac{j972 \times 10}{[j972 + 10]} = 9.99\angle 0.58^\circ\ \Omega$.

Q :- Find L_{eq} if :-

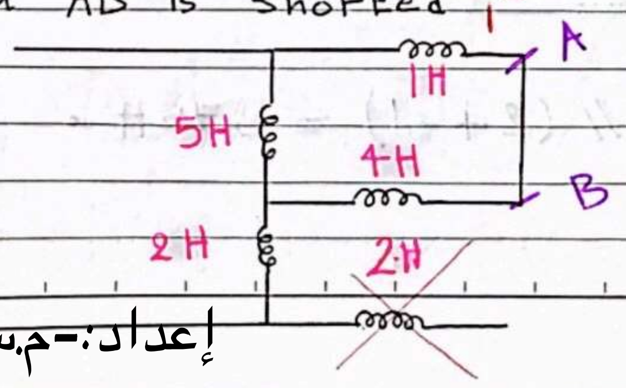


① When there are no connection between A and B and C :-



$L_{eq} = 2 + -1 = 1H$.

② When AB is shorted :-



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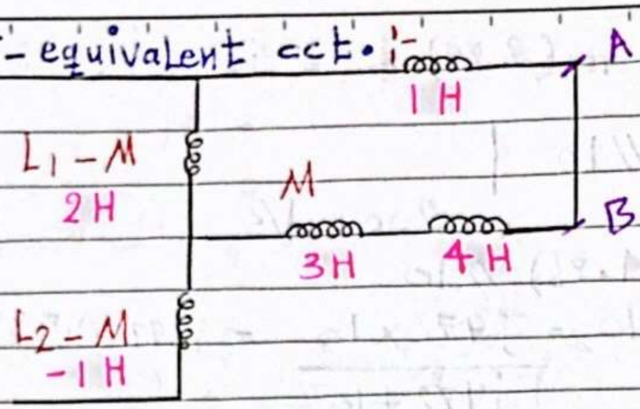
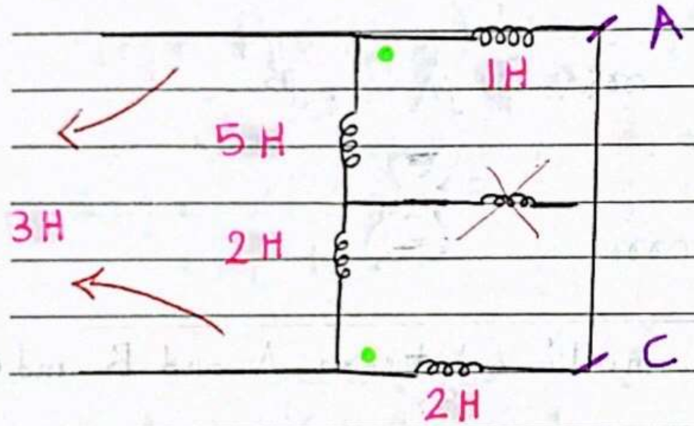
T- equivalent cct. :-

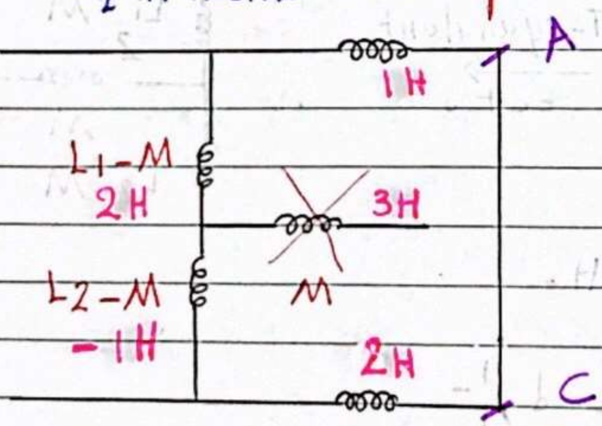


$$L_{eq} = \left[(3+4+1) \,//\, 2\right] + -1 = 0.6 \text{ H}.$$

③ When AC is shorted :-

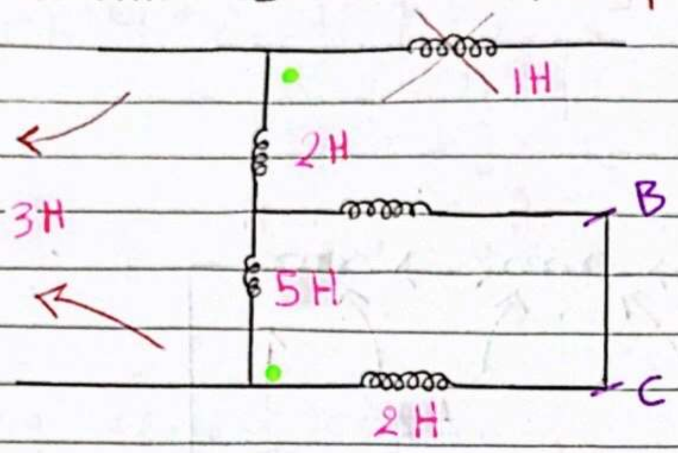


T- equivalent cct. :-

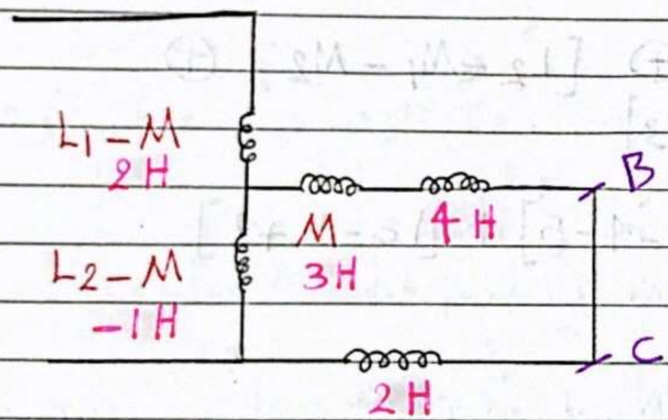


$$L_{eq} = (1+2) \,//\, (2 + -1) = 0.75 \text{ H}.$$

④ When BC is shorted :-

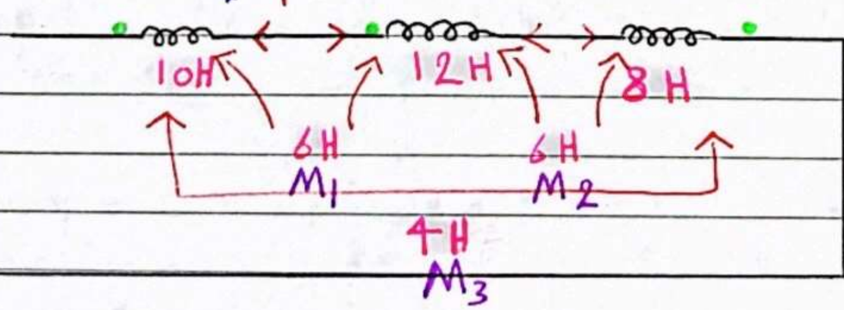


T - equivalent cct. :-



$$L_{eq} = [(3+4+2) \,//\, -1] + 2 = 0.875H.$$

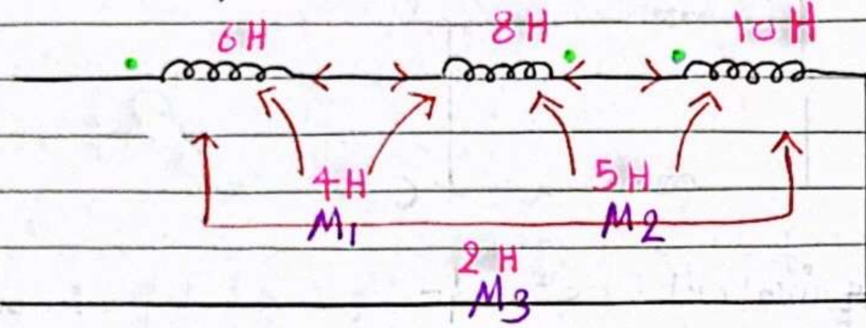
⑦ :- Find L_{eq} :-



$$L_{eq} = [L_1 + M_1 - M_3] \oplus [L_2 - M_2 + M_1] \oplus [L_3 - M_2 - M_3]$$

$$L_{eq} = [10+6-4] + [12-6+6] + [8-6-4]$$
$$= 22\text{ H}.$$

Q:- Find L_{eq}:-



$$L_{eq} = [L_1 - M_1 + M_3] \oplus [L_2 - M_1 - M_2] \oplus [L_3 - M_2 + M_3]$$

$$L_{eq} = [6-4+2] + [8-4-5] + [10-5+2]$$
$$= 10\text{ H}.$$

أطال الله في عمر اللحظات المليئة
بالرضى ، الرضى الذي ينبعُ من
الداخل ليبدو مُشرقًا على ظاهرك

CH :- "complex frequency" :-

$$S = \sigma + jw$$

σ ↓ Real part

jw ↓ Imaginary part

s :- complex frequency , (second)$^{-1}$ / (s)$^{-1}$.
σ :- neper frequency , (neper/sec.) .
w :- (radian / angular) frequency , (rad/sec.) .

∴ Note :-
في ال [complex frequency] إما [2 parts] بكونوا موجودين أو أحدهما صفر .

– general form for any function :-

$$f(t) = K e^{s(t)}$$

K :- constant .
s(t) :- complex frequency .

* There are four cases for [s(t)] :-

1- $s(t) = \text{zero} \rightarrow f(t) = Ke^{0} = K = \text{constant}$
$\rightarrow$ D.C source (لا تتغير مع الزمن) . $w/\sigma = \text{zero}$

2- $s(t) = \sigma \rightarrow f(t) = Ke^{\sigma t} \rightarrow$ exponential function . $w = \text{zero}$
σ + increasing
σ – decreasing

3- $s(t) = jw \longrightarrow f(t) = Ke^{jwt} \longrightarrow$
$s(t) = [K\cos wt + jK\cos wt] \longrightarrow$ sinusoidal function . $\sigma = \text{zero}$

4- $s(t) = \sigma + jw \longrightarrow F(t) = K e^{(\sigma + jw)t} \longrightarrow$

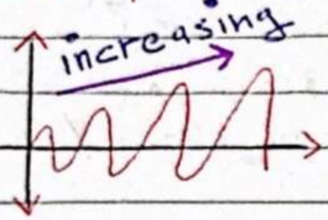
$f(t) = K e^{\sigma t} [\cos wt + \sin wt] \longrightarrow$

damped sinusoidal Function.

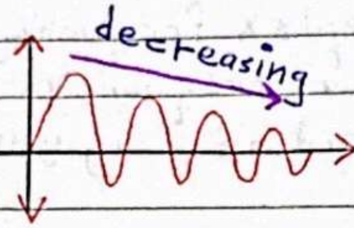
$\sigma +$ increasing

$\sigma -$ decreasing

∴ Note :-



$\sigma +$



$\sigma -$

$$
\begin{aligned}
* \quad V(t) &= V_m \cos (wt + \theta) \\
&= V_m \, e^{j(wt+\theta)} \\
&= V_m \left[\frac{e^{j(wt+\theta)} + e^{-j(wt+\theta)}}{2} \right] \\
&= \frac{V_m}{2} \left[e^{jwt} e^{j\theta} + e^{-jwt} e^{-j\theta} \right] \\
&= \frac{V_m}{2} e^{jwt} e^{j\theta} + \frac{V_m}{2} e^{-jwt} e^{-j\theta} \\
&= \underbrace{\frac{V_m}{2} e^{j\theta}}_{K_1} \underbrace{e^{jwt}}_{e^{s_1 t}} + \underbrace{\frac{V_m}{2} e^{-j\theta}}_{K_2} \underbrace{e^{-jwt}}_{e^{s_2 t}} \\
&= K_1 e^{s_1 t} + K_2 e^{s_2 t}.
\end{aligned}
$$

so :- $K_1 = \frac{V_m}{2} e^{j\theta}$ / $K_2 = \frac{V_m}{2} e^{-j\theta}$

$K_1 = K_2^*$.

$s_1 = j\omega$ / $s_2 = -j\omega$ / $s_1 = s_2^*$.

Q :- Find complex Frequency :-

1- $v(t) = 2\cos(5t + 50^\circ)$

$s_1 = +j5 \ s^{-1}$.

$s_2 = -j5 \ s^{-1}$.

2- $v(t) = 5\sin(10t - 50^\circ)$

$v(t) = 5\cos(10t - 50^\circ - 90^\circ)$

$v(t) = 5\cos(10t - 140^\circ)$.

sol :- $s_1 = +j10 \ s^{-1}$.

$s_2 = -j10 \ s^{-1}$.

3- $(2e^{-100t} + e^{-200t})\sin(5000t)$

$2e^{-100t}\sin(5000t) + e^{-200t}\sin(5000t)$

$s_1 = -100 + j5000 \ s^{-1}$.

$s_2 = -100 - j5000 \ s^{-1}$.

$s_3 = -200 + j5000 \ s^{-1}$.

$s_4 = -200 - j5000 \ s^{-1}$.

4- $(2 - e^{-10t})\cos(4t + \theta^\circ)$

$2\cos(4t + \theta^\circ) - e^{-10t}\cos(4t + \theta^\circ)$

$s_1 = +j4 \ s^{-1}$.

$s_2 = -j4 \ s^{-1}$.

$s_3 = -10 + j4 \ s^{-1}$.

$s_4 = -10 - j4 \ s^{-1}$.

5- $e^{-10t}\cos(10t)\sin(40t)$

$s_1 = -10 + j10 + j40 = [-10 + j50]\ s^{-1}$.
$s_2 = -10 + j10 - j40 = [-10 - j30]\ s^{-1}$.
$s_3 = -10 - j10 + j40 = [-10 + j30]\ s^{-1}$.
$s_4 = -10 - j10 - j40 = [-10 - j50]\ s^{-1}$.

Q :- construct a Function with Following Frequency :-

1- $s = 0 , 10 , -10\ s^{-1}$
$v(t) = [K_1 + K_2 e^{10t} + K_3 e^{-10t}]$.

∴ Note :-
الفواصل الموجودة بين الأرقام تدل على أن كل رقم يمثل حد .

2- $s = -5 , j8 , -5 + j8$
حل :- $v(t) = [K_1 e^{-5t} + K_2 \sin 8t + K_3 e^{-5t} \sin 8t]$.
$v(t) = [K_1 e^{-5t} + K_2 \cos 8t + K_3 e^{-5t} \cos 8t]$.

∴ Note :-
بجيب اما sin أو cos كما في الفرع الثاني سابقاً .

Q :- If $V = \underset{K}{10} \underset{\theta}{\angle 50^\circ}$ V , Find v(t) when :-

هنا المطلوب منا نكتب v(t) على صورة :-
$v(t) = K e^{\sigma t} \cos(wt + \theta)$
or $v(t) = K e^{\sigma t} \sin(wt + \theta)$

1- $s_1 = 0\ s^{-1}$.
$v(t) = 10 e^{0t} \cos(0t + 50^\circ)$
$= 10 \cos 50^\circ = 6.43$ V .

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2- $s_2 = -20\ s^{-1}$.

$$V(t) = 10\, e^{-20t} \cos(0t + 50°) = 10 e^{-20t} \cos 50°$$
$$= 6.43\, e^{-20t}\ V.$$

3- $s_3 = j5\ s^{-1}$.

$$V(t) = 10\, e^{0t} \cos(5t + 50°) = 10 \cos(5t + 50°)\ V.$$

4- $s_4 = -20 + j50\ s^{-1}$.

$$V(t) = 10\, e^{-20t} \cos(50t + 50°)\ V.$$

Q :- Find complex frequency :-

$$V(t) = 12 e^{-2t} + e^{-5t} \cos(50t - 210°)\ V.$$

$s_1 = -2\ s^{-1}$.

$s_2 = -5 + j50\ s^{-1}$.

$s_3 = -5 - j50\ s^{-1}$.

- Damped sinusoidal Forcing function :-

$$\left.\begin{array}{l} V(t) = V_m \angle\theta° \longrightarrow V_m e^{j\theta} \\ I(t) = I_m \angle\theta° \longrightarrow I_m e^{j\theta} \end{array}\right\}$$ [phasor Form]

- بدلالة الـ [complex frequency] :-

$$V(t) = V e^{st} \longrightarrow V = V_m \angle\theta° \longrightarrow V_m e^{j\theta}$$
$$I(t) = I e^{st} \longrightarrow I = I_m \angle\theta° \longrightarrow I_m e^{j\theta}$$

Q :- Find phasor form and s :-

1- $24 \sin(10t + 60°)$.

$24 \cos(90t + 60° - 90°)$

$24 \cos(90t - 30°)$

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- phasor form :- $24 \angle -30^\circ$.
- $s = \mp j90 \ s^{-1}$.

∴ Note :-

الـ [complex frequency] لا يختلف إزا كان عندي [sin / cos]
ولكن في حال طلب كتابة الـ [phasor form] لازم أحول إلى cos .

2- $24 e^{-10t} \cos(90t + 60^\circ)$.

- phasor form :- $24 \angle 60^\circ \times e^{-10t}$.
- $s = -10 \mp j90 \ s^{-1}$.

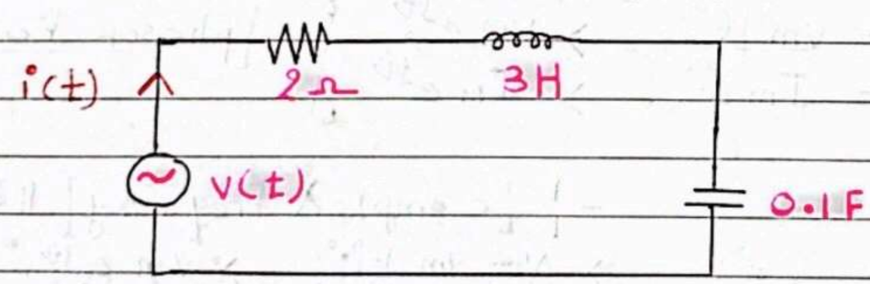
3- $28 e^{-5t} \cos 60^\circ \sin 90t$

$14 e^{-5t} \sin 90t$

$14 e^{-5t} \cos(90t - 90^\circ)$

- phasor form :- $14 \angle -90^\circ \times e^{-5t}$.
- $s = -5 \mp j90 \ s^{-1}$.

Q :- $v(t) = 60 e^{-2t} \cos(4t + 10^\circ)$, Find $i(t)$:-



- $v(t) = i(t) R + L \frac{di}{dt} + \frac{1}{C} \int i \, dt$

$= 2I + 3 \frac{di}{dt} + \frac{1}{0.1} \int i \, dt$.

- $v(t) = 60 \angle 10^\circ \, e^{-2t} \longrightarrow s = -2 \mp j4$.
$I(t) = I_m \angle \theta^\circ \, e^{st} \longrightarrow s = 6 \mp jw$.

- $s = jw$:-
sol:- $Z_L = jwL = sL$.
$Z_c = \frac{1}{jwc} = \frac{1}{sc}$.

- sol:-
$$60 \angle 10^\circ \, e^{-st} = 2 I_m e^{st} + 3s I_m e^{st} + \frac{1}{0.1s} I_m e^{st}$$
$$60 \angle 10^\circ = 2 I_m + 3s I_m + \frac{I_m}{0.1s}$$
$$60 \angle 10^\circ = \left[2 + 3s + \frac{1}{0.1s}\right] I_m$$
$$I_m = \frac{60 \angle 10^\circ}{2 + 3s + \frac{1}{0.1s}}$$
$s = -2 \mp j4$
$$I_m = \frac{60 \angle 10^\circ}{2 + 3(-2+j4) + \frac{1}{0.1(-2+j4)}}$$
$$I_m = \underbrace{5.37}_{\text{Magnitude}} \, \underbrace{\angle -106.6^\circ}_{\theta} \text{ A}.$$

sol:- $i(t) = 5.37 \cos(4t - 106.6^\circ) e^{st}$
$= 5.37 \cos(4t - 106.6^\circ) e^{-2}$.

- Laplace transform :-
The convertion from time domain to complex frequency domain [S].
$$F(s) = \int_{-\infty}^{\infty} f(t) \cdot e^{-st} \cdot dt$$

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$$f(t) \Longleftrightarrow F(s)$$

↳ هذا السهم يدل على أنه يمكن التحويل بين [time domain] والـ [Frequency domain] .

- $\mathcal{L}\, f(t) = F(s)$.

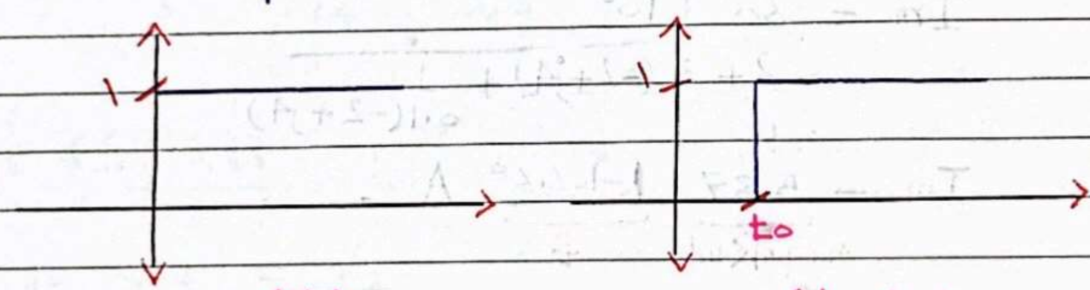
Laplace ←

- $\mathcal{L}\, F(s) = f(t)$.

Laplace inverse ←

∴ Note :-

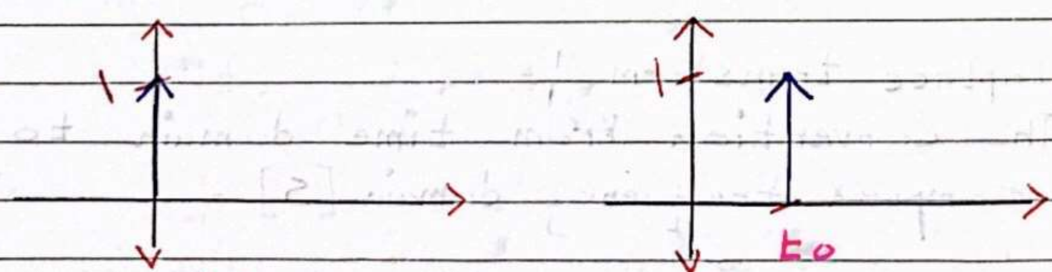
- unit step function $[u(t)]$:-



$u(t)$ $u(t-t_0)$

↳ الإزاحة

- impulse function $[\delta(t)]$:-



$\delta(t)$ $\delta(t-t_0)$

↳ الإزاحة

Time domain	Frequency domain
- $A u(t)$	$\frac{A}{s}$
- $A u(t-t_0)$	$\frac{A}{s} e^{-t_0 s}$
- $A e^{-at} u(t)$	$\frac{A}{(s+a)}$
- $A e^{at} u(t)$	$\frac{A}{(s-a)}$
- $A t\, u(t)$	$\frac{A}{s^2}$
- $A t e^{-at} u(t)$	$\frac{A}{(s+a)^2}$
- $\delta(t)$	1
- $\sin(wt)\, u(t)$	$\frac{w}{s^2+w^2}$
- $\cos(wt)\, u(t)$	$\frac{s}{s^2+w^2}$
- $\delta(t-t_0)$	$e^{-t_0 s}$

initial value

- $\mathcal{L}\left(\frac{dv}{dt}\right) \longrightarrow s V(s) - v(0^-)$

- $\mathcal{L}\left(\frac{d^2v}{dt^2}\right) \longrightarrow s^2 V(s) - s v(0^-) - v'(0^-)$

- $\mathcal{L}\left(\frac{d^3v}{dt^3}\right) \longrightarrow s^3 V(s) - s^2 v(0^-) - s \dot{v}(0^-) - v''(0^-)$

إعداد:-م.سجى البزايعه

Q :- Find V(s) or convert to frequency domain :-

1- $v(t) = 4\delta(t) - 3u(t)$

$V(s) = 4 - \frac{3}{s}$.

2- $v(t) = 4\delta(t-2) - 3t\,u(t)$

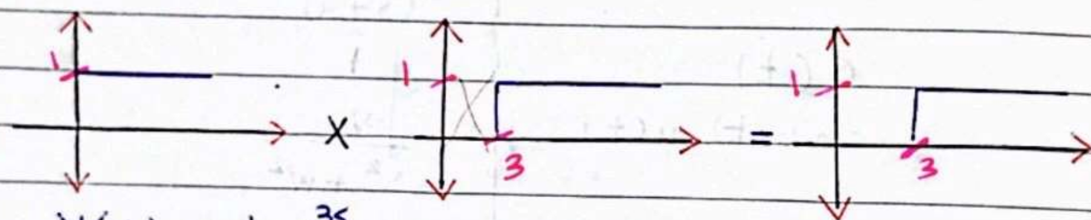
$V(s) = 4e^{-2s} - \frac{3}{s^2}$.

3- $v(t) = 10t\,u(t)$

$V(s) = \frac{10}{s^2}$.

4- $v(t) = u(t) \cdot u(t-3) = u(t-3)$

بالرسم



$V(s) = \frac{1}{s} e^{3s}$.

Q :- Find v(t) or convert to time domain :-

1- $V(s) = \frac{10}{s}$

$v(t) = 10\,u(t)$.

2- $V(s) = \frac{12}{s^2}$

$v(t) = 12\,t\,u(t)$.

∴ Note :-

إذا طلب التحويل إلى [time domain] وكان الـ Function
المعطى على صورة ($\frac{\text{بسط}}{\text{مقام}}$) ولا يمكن حله مباشرة من الجدول السابق

فهنالك طريقتين للحل :- $\boxed{H(s) = \frac{N}{D}}$

- $N < D$ (الرتبة) $\longrightarrow$ partial Fraction.
- $N \geq D$ (الرتبة) $\longrightarrow$ Long division.

3- $V(s) = \dfrac{10}{s(s+10)}$ $\begin{matrix} \longrightarrow \text{الرتبة الصفرية} \\ \longrightarrow \text{الرتبة الثانية} \end{matrix}$ $\Big\}$ partial Fraction

- $\dfrac{10}{s(s+10)} = \dfrac{A}{s} + \dfrac{B}{(s+10)}$

$A(s+10) + Bs = 10 \longrightarrow A(s+10) + Bs = 10 + 0s$

$As + 10A + Bs = 10$

sol:- $10A = 10 \longrightarrow \boxed{A = 1}$

$A + B = 0 \longrightarrow \boxed{B = -1}$

sol:- $V(s) = \dfrac{1}{s} + \dfrac{-1}{(s+10)}$

$V(t) = u(t) - e^{-10t}u(t)$.

4- $V(s) = \dfrac{10s}{s+10}$ $\begin{matrix} \longrightarrow \text{الرتبة الأولى} \\ \longrightarrow \text{الرتبة الأولى} \end{matrix}$ $\Big\}$ Long division

$$\begin{array}{r|l} & \ 10 \\ \hline s+10 & \ \cancel{10s} \\ & \ \cancel{-10s} \mp 100 \\ \hline & \ -100 \end{array}$$

- $V(s) = 10 + \dfrac{-100}{(s+10)}$

$V(t) = 10\,\delta(t) - 100\,e^{-10t}\,u(t)$

$\left[\text{الناتج} + \dfrac{\text{الباقي}}{\text{المقسوم عليه}} \right]$

5- $F(s) = \frac{2s+4}{s} = \frac{2s}{s} + \frac{4}{s} = 2 + \frac{4}{s}$

$f(t) = 2\,\delta(t) + 4u(t)$.

6- $F(s) = \frac{7s+5}{s(s+1)}$ → الرتبة الأولى / الرتبة الثانية → partial fraction

- $\frac{7s+5}{s(s+1)} = \frac{A}{s} + \frac{B}{(s+1)}$

$A(s+1) + Bs = 7s+5$

$As + A + Bs = 7s + 5$

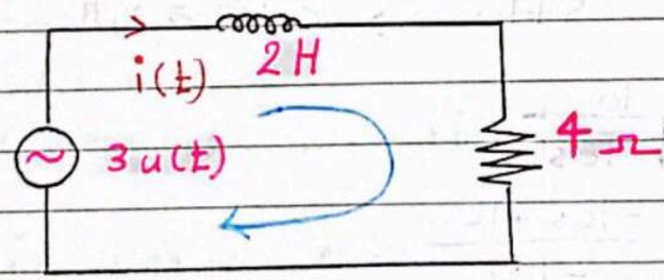
$\boxed{A = 5}$

$A + B = 7 \longrightarrow \boxed{B = 2}$

- sol:- $F(s) = \frac{5}{s} + \frac{2}{(s+1)}$

$f(t) = 5u(t) + 2e^{-t}u(t)$.

Q:- $i(0^-)$ [initial value] = 5A , Find $i(t)$:-



$\mathcal{L}\{3u(t)\} = \mathcal{L}\{L\frac{di}{dt} + IR\}$

$\frac{3}{s} = L\,[sI(s) - I(0^-)] + I(s) \times R$

$\frac{3}{s} = 2sI(s) - 2\times 5 + 4I(s)$

$$\frac{3}{s} = 2s\,I(s) - 10 + 4\,I(s)$$

$$\frac{3}{s} + 10 = I(s)\,[2s + 4]$$

$$I(s) = \frac{\frac{3}{s} + 10}{2s + 4} \quad , \quad I(s) = \frac{3 + 10s}{s(2s+4)} \rightarrow \text{partial fraction}$$

- $$\frac{3 + 10s}{s(2s+4)} = \frac{A}{s} + \frac{B}{(2s+4)}$$

$$A(2s+4) + Bs = 3 + 10s$$

$$2As + 4A + Bs = 3 + 10s$$

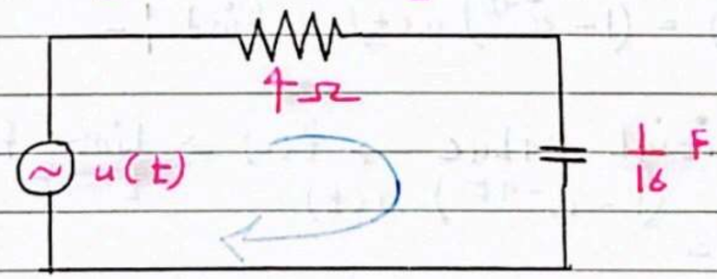
- $4A = 3 \rightarrow \boxed{A = 3/4}$
- $2A + B = 10 \rightarrow \boxed{B = 8.5}$

sol :- $$I(s) = \frac{3}{4s} + \frac{8.5}{2s+4}$$

$$I(s) = \frac{3}{4s} + \frac{8.5}{2(s+2)} \quad , \quad I(s) = \frac{3}{4s} + \frac{4.25}{(s+2)}$$

$$i(t) = \frac{3}{4}u(t) + 4.25\,u(t)\,e^{-2t}.$$

Q :- $v(0^-)$ [initial value] = 9v , Find i(t) :-



- $$u(t) = i(t)R + \frac{1}{C}\int i(t)\,dt$$

$$\mathcal{L}\{u(t)\} = \mathcal{L}\left\{4i(t) + \frac{1}{16}\Big[\underbrace{\int_{-\infty}^{0} i(t)\,dt}_{\text{initial value}} + \int_{0}^{\infty} i(t)\,dt\Big]\right\}$$

$$\frac{1}{s} = 4\,I(s) + \frac{9}{s} + \frac{16\,I(s)}{s}$$

$$\frac{1}{s} - \frac{9}{s} = \left[4 + \frac{16}{s}\right] I(s)$$

$$I(s) = \frac{\frac{-8}{s}}{4+\frac{16}{s}} = \frac{\frac{-8}{s}}{\frac{4s+16}{s}} = \frac{-8}{4s+16} = \frac{-8}{4(s+4)}$$

sol:- $I(s) = \dfrac{-2}{(s+4)}$

$$i(t) = -2u(t)\,e^{-4t}\ A.$$

- Initial value and final value :-
- Initial value $\longrightarrow f(0)$.
- Final value $\longrightarrow f(\infty)$

- $f(0) \longrightarrow \lim\limits_{t\to 0} f(t) \longrightarrow \lim\limits_{s\to\infty} s\,F(s)$.

$f(\infty) \longrightarrow \lim\limits_{t\to\infty} f(t) \longrightarrow \lim\limits_{s\to 0} s\,F(s)$.

Q :- $f(t) = (1-e^{-at})\,u(t)$, find :-

- Initial value $\longrightarrow f(0) \Rightarrow \lim\limits_{t\to 0} f(t) \longrightarrow$

$= \lim\limits_{t\to 0} (1-e^{-at})\,u(t)$

$= 1 - e^{0}\,u(0) = 1-1 = \text{Zero}.$

- Final value $\longrightarrow f(\infty) \Rightarrow \lim\limits_{t\to\infty} f(t) \longrightarrow$

$= \lim\limits_{t\to\infty} (1-e^{-at})\,u(t)$

$= 1-e^{\infty}\,u(\infty) = 1-0 = 1.$

Q :- $F(s) = \frac{1}{s} - \frac{1}{s+a}$, find :-

- Initial value → $f(0) \Rightarrow \lim_{s\to\infty} sF(s) =$

$= \lim_{s\to\infty} \frac{s}{s} - \frac{s}{s+a}$

$= \lim_{s\to\infty} 1 - \frac{\infty}{\infty} = \lim_{s\to\infty} 1 - 1 =$ Zero .

- Final value → $f(\infty) \Rightarrow \lim_{s\to 0} sF(s) =$

$= \lim_{s\to 0} \frac{s}{s} - \frac{s}{s+a}$

$= \lim_{s\to 0} 1 - \frac{0}{0+a} = \lim_{s\to 0} 1 - 0 = 1$.

وأسألك يارب أن يأتي القادم
من أيام العمر بأنعم طريقة
ممكنة ، أن تمر الأيام بأدفئ
شعور ممكن

إعداد:-م.سجى البزايعه

CH :- "Circuit Analysis in S domain" :-

1] For resistor :-

- $V(t) = i(t) \times R \rightarrow$ [time domain].

Laplace $\leftarrow \mathcal{L}\, V(t) = \mathcal{L}\, i(t) \times R$

- $V(S) = I(S) \times R \rightarrow$ [Frequency domain].

- $R = \frac{V(S)}{I(S)} = Z_R(s) \rightarrow$ Impedence.

2] For inductor :-

- $V_L(t) = L \frac{di}{dt} \longrightarrow$ [time domain].

Laplace $\leftarrow \mathcal{L}\, V_L(t) = \mathcal{L}\, L \frac{di}{dt}$

- $V_L(S) = L\left[sI(s) - I(\bar{0})\right]$

$\hookrightarrow$ initial value

$V_L(S) \Big|_{I(\bar{0}) = Zero} = Ls\, I(s)$

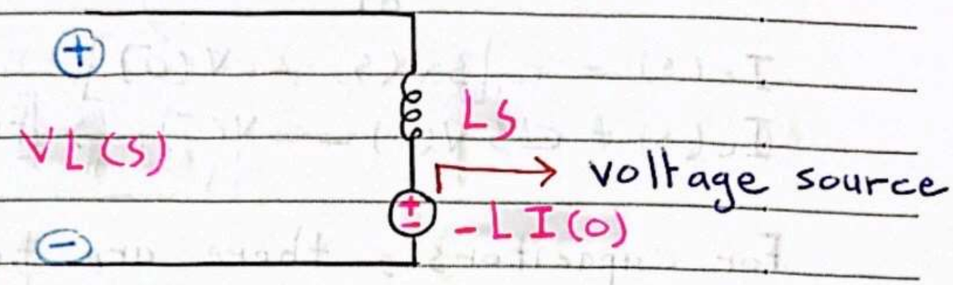
- $\underset{\downarrow \, (jw)}{Ls} = \frac{V_L(S)}{I_L(S)} = Z_L(s) \longrightarrow$ Impedence.

- For inductors , there are two models :-

إعداد:-م.سجى البزايعه

1] voltage model :- [لازم نخلي VL(s) موضوع قانون]

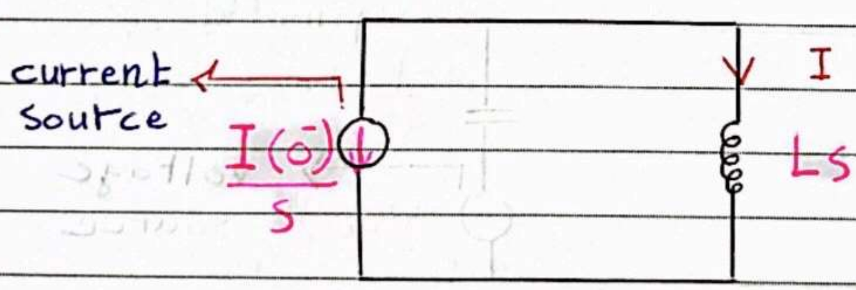
$$V_L(s) = Ls\,I(s) - L\,I(\bar{0})$$



2] current model :- [لازم نخلي IL(s) موضوع قانون]

$$I_L(s) = \frac{V_L(s) + L\,I(\bar{0})}{Ls}$$

so :- $I_L(s) = \frac{V_L(s)}{Ls} + \frac{I(\bar{0})}{s}$



∴ Note :-

بالنسبة لل [inductors] بإمكانك الحل على اي model تريده .

3] For capacitor :-

- $i_c = c \dfrac{dv_c}{dt} \longrightarrow$ [time domain].

Laplace $\longleftarrow \mathcal{L}\, i_c = \mathcal{L}\, c \dfrac{dv_c}{dt}$

- $I_c(s) = c\left[sV(s) - V(0^-)\right]$

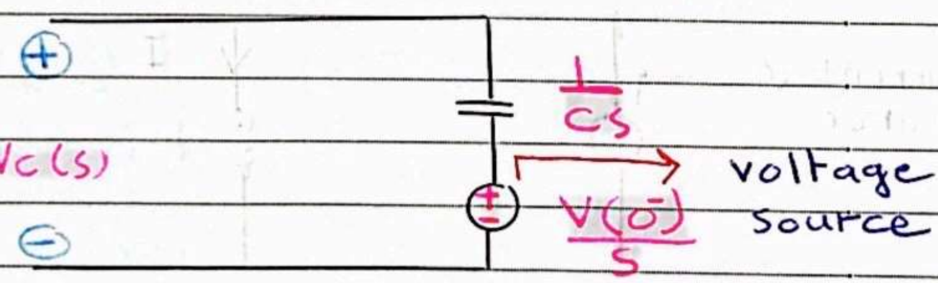
$I_c(s) = CsV(s) - cV(0^-) \longrightarrow$ [Frequency domain].

- For capacitors, there are two models :-

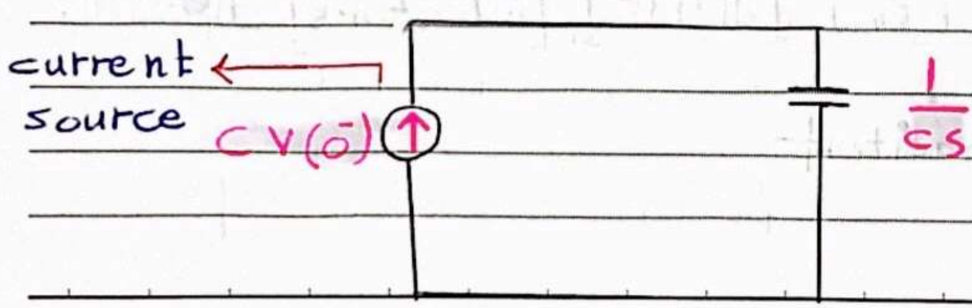
1] voltage model :-

$$V_c(s) = \frac{I_c(s) + cV(0^-)}{Cs}$$

so :- $V_c(s) = \dfrac{I_c(s)}{Cs} + \dfrac{V(0^-)}{s}$.



2] current model :-

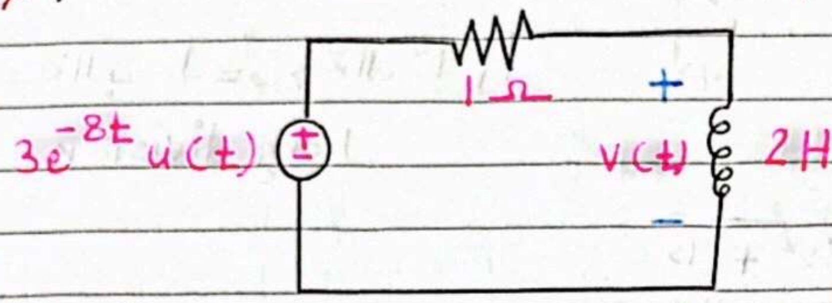


إعداد:-م.سجى البزايعه

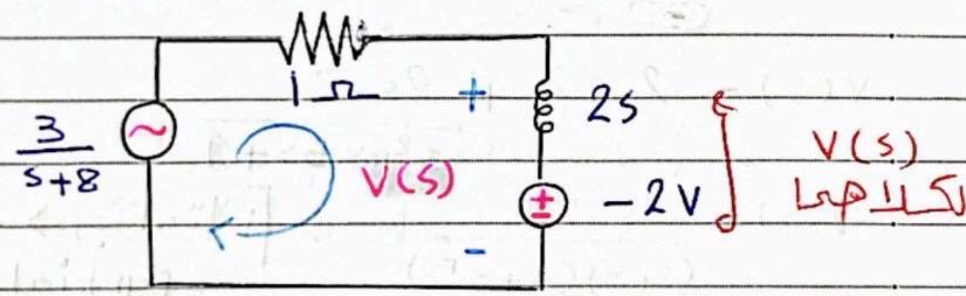
∴ Note :-

بالنسبة للـ capacitors بإمكانك الحل على الـ model الذي تريده .

Q :- Find v(t) , if i(0) = 1A :-



- Firstly convert the circuit above to S domain :-



* طبعاً أنا هون اخترت أحل على الـ [Voltage model] :-

- $\mathcal{L}\{3e^{-8t}u(t)\} = \frac{3}{s+8}$.
- $\mathcal{L}\{R(t)\} = R(s) = 1\Omega$.
- $\mathcal{L}\{L(t)\} = Ls = 2s\ H$.
- Voltage source :- $-LI(0^-) = -2\times1 = -2$.
- KVL at the Loop :-

$$-\frac{3}{s+8} + I(s) + 2s\,I(s) - 2 = \text{Zero}$$

So :- $I(s) = \dfrac{s+9.5}{(s+0.5)(s+8)}$.

إعداد:-م.سجى البزايعه

sol:- $V(s) = 2s\,I(s) - 2$

$= 2 \times s \times \dfrac{(s+9.5)}{(s+0.5)(s+8)} - 2$

$= \dfrac{2s^2 + 19s}{(s+8)(s+0.5)} - 2$

[درجة البسط = درجة المقام]

Long division

$$\begin{array}{r|l} & \times 2 \\ s^2+8.5s+4 & 2s^2 + 19s \\ & \cancel{2s^2} + 17s + 8 \\ \hline & 2s - 8 \end{array}$$

- $V(s) = \cancel{2 - 2} + \dfrac{2s-8}{s^2+8.5s+4}$

$V(s) = \dfrac{2s-8}{(s+8)(s+0.5)}$ → [درجة البسط < درجة المقام]

partial Fraction

- $\dfrac{2s-8}{(s+8)(s+0.5)} = \dfrac{A}{(s+8)} + \dfrac{B}{(s+0.5)}$

$A(s+0.5) + B(s+8) = 2s-8$

$As + 0.5A + Bs + 8B = 2s - 8$

sol:- $A\cancel{s} + B\cancel{s} = 2\cancel{s} \rightarrow A + B = 2$ ... ①

$0.5A + 8B = -8$ ... ②

sol:- ① × −8 + ② :-

$$-8A - \cancel{8B} = -16$$
$$0.5A + \cancel{8B} = -8$$

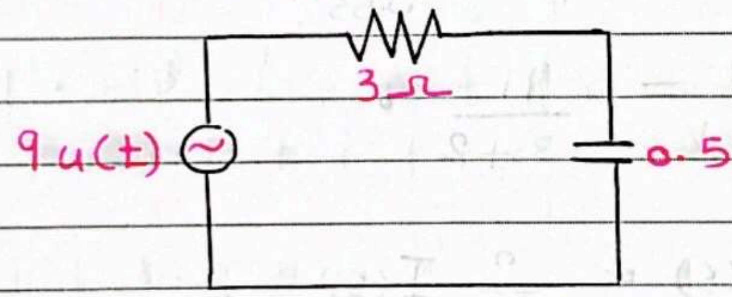
$$\frac{-7.5A}{-7.5} = \frac{-24}{-7.5} \longrightarrow \boxed{A = 3.2}$$

$$-\quad 3.2 + B = 2 \longrightarrow \boxed{B = -1.2}$$

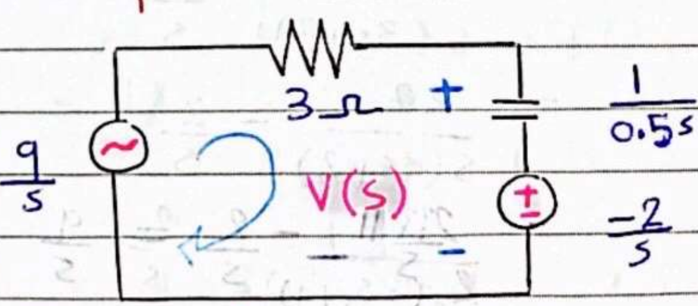
Sol :- $V(S) = \dfrac{3.2}{(S+8)} + \dfrac{-1.2}{(S+0.5)}$

$$v(t) = 3.2e^{-8t}u(t) + -1.2e^{-0.5t}u(t).$$

Q :- Find $v_c(t)$, if $v_c(0^-) = -2\,V$.



- Firstly convert the circuit above to S domain :-



* طبعًا انا هون اخترت اشتغل على [Voltage model] :-

- $\mathcal{L}\, 9u(t) = \frac{9}{s}$.

- $\mathcal{L} R(t) = R(s) = 3\Omega$.
- $\mathcal{L}\, c(t) = \frac{1}{cs} = \frac{1}{0.5s}$.

- Voltage source :- $\frac{V(\bar{0})}{s} = \frac{-2}{s}$.
- KVL at the Loop :-

$$\frac{-9}{s} + 3I(s) + \frac{1}{0.5s}I(s) - \frac{2}{-s} = \text{Zero}$$

Sol :- $I(s) = \dfrac{\frac{9}{s} + \frac{2}{s}}{3 + \frac{1}{0.5s}}$

$$= \frac{11}{3s+2}.$$

Sol :- $V(s) = \frac{2}{s} I(s) - \frac{2}{s}$

$$= \frac{2 \times 11}{s(3s+2)} - \frac{2}{s}$$

$$= \frac{22}{s(3s+2)} - \frac{2}{s}$$

$$= \frac{22}{3s(s+\frac{2}{3})} - \frac{2}{s}$$

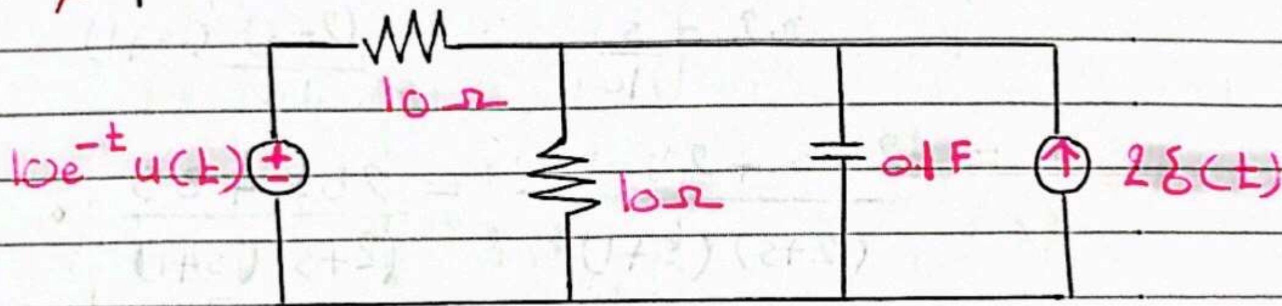
$$= \frac{22}{3s} - \frac{2}{s} + \frac{22}{\left(s+\frac{2}{3}\right)}$$

$$= \frac{16}{3s} + \frac{22}{\left(s+\frac{2}{3}\right)}$$

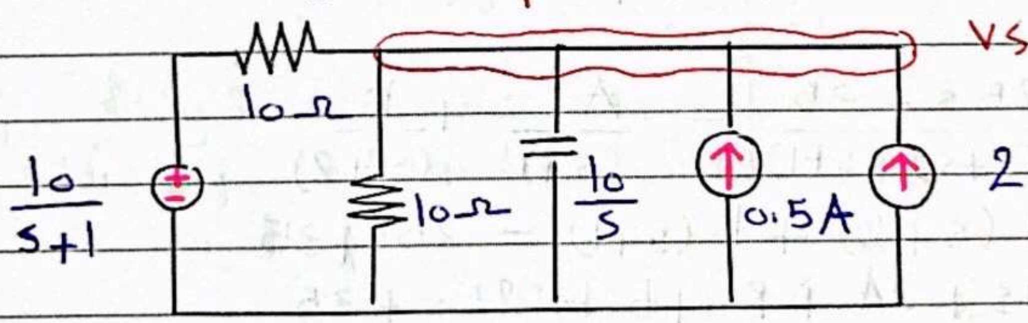
$$V(s) = \frac{5.3}{s} + \frac{22}{\left(s+\frac{2}{3}\right)} .$$

$$v(t) = 5.3\,u(t) + 22 e^{-\frac{2}{3}t}\,u(t) .$$

Q :- Find $v(t)$, if $v(0^-) = 5V$:-



- Firstly convert the circuit above to s Domain :-



- $f\ c(t) = \frac{1}{cs} = \frac{10}{s}$.

- current source :- $c\,v(0^-) = 0.1 \times 5 = 0.5A$.

* إحنا هون حلينا على ال [current model] .

- by using Nodal analysis :-

$$\frac{V_s - \frac{10}{s+1}}{10} + \frac{V_s}{10} + \frac{V_s}{\frac{10}{s}} = 2 + 0.5$$

$$\frac{V_s\,\cancel{(s+1)}}{\cancel{(s+1)}\,10} - \frac{\cancel{10}}{(s+1)\cancel{(10)}} + \frac{V_s}{10} + \frac{V_s \times s}{10} = 2.5$$

$$V(s) = \frac{2.5 + \frac{1}{(s+1)}}{0.2 + \frac{s}{10}} = \frac{2.5(s+1) + 1}{\frac{(2+s)}{10}(s+1)}$$

$$= \frac{25s + 25 + 10}{(2+s)(s+1)} = \frac{25s + 35}{(2+s)(s+1)}$$

[درجة البسط < درجة المقام]

partial Fraction

$$\frac{25s + 35}{(2+s)(s+1)} = \frac{A}{(s+1)} + \frac{B}{(s+2)}$$

$$A(s+2) + B(s+1) = 25s + 35$$

$$As + 2A + Bs + B = 25s + 35$$

sol:- $A\cancel{s} + B\cancel{s} = 25\cancel{s} \quad \ldots (1)$

$2A + B = 35 \quad \ldots (2)$

sol:- $(1) \times -2 + (2)$:-

$$-2\cancel{A} + -2B = -50$$

$$\cancel{2A} + B = 35$$

إعداد:-م.سجى البزايعه

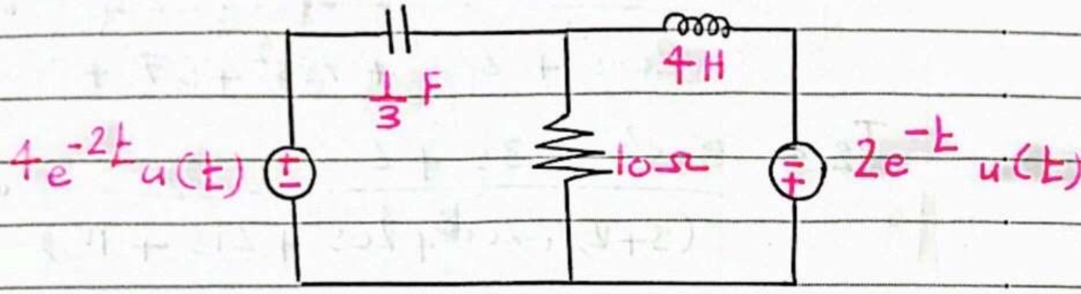
$-B = -15 \longrightarrow \boxed{B=15}$

$A + 15 = 25 \longrightarrow \boxed{A=10}$

Sol:- $V(S) = \dfrac{10}{(s+1)} + \dfrac{15}{(s+2)}$

$v(t) = 10e^{-t}u(t) + 15e^{-2t}u(t)$.

Q:- Find mesh currents if there is no stored energy:-

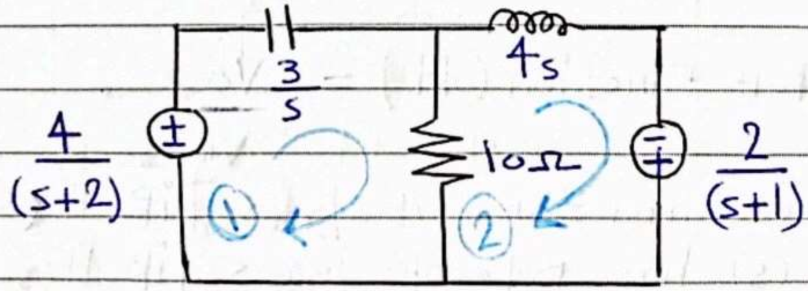


∴ Note:-

No stored energy $\longrightarrow I_L(0^-) = \text{Zero}$.

$V_c(0^-) = \text{Zero}$.

- Firstly we convert the circuit above to s domain:-



∴ Note:-

في حالة ذكر بالسؤال [no stored energy] فعندما نحول
إلى [S domain] وفي حالة استخدام اي [model]

فإن قيمة ال [voltage source] or [current source] المضاف تساوي صفر.

- KVL at Loop 1 :-

$$\frac{3}{s} I_1 + 10 (I_1 - I_2) - \frac{4}{(s+2)} = \text{Zero}$$

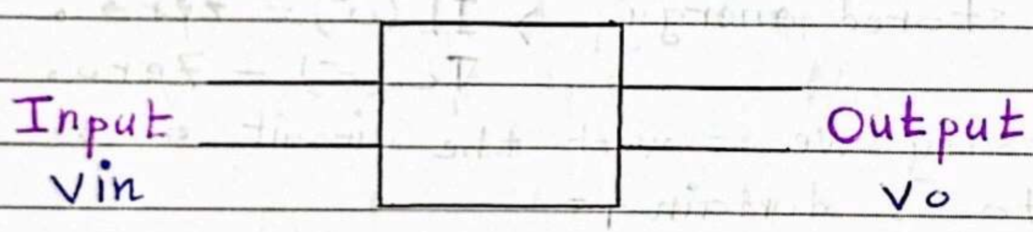
- KVL at Loop 2 :-

$$4s I_2 + 10 (I_2 - I_1) - \frac{2}{s+1} = \text{Zero}$$

sol :-
$$I_1 = \frac{25 (4s^2 + 19s + 20)}{20s^4 + 66s^3 + 73s^2 + 57s + 30}.$$

$$I_2 = \frac{30s^2 + 43s + 6}{(s+2)(20s^3 + 26s^2 + 21s + 15)}.$$

- Transfer Function :-



$$\text{Transfer Function } (H) = \frac{V_o}{V_{in}}.$$

* $H(s)$ has Zero at $[s = s_o]$ if $H(s_o) = \text{Zero}$.
* $H(s)$ has pole at $[s = s_o]$ if $H(s_o) = \infty$

← بمعنى آخر هي القيم التي تصفر المقام فقط.

① :- $H(s) = \frac{1}{1+9s}$ و Find Zeros and poles :-

- Zeros :- $H(s) = Zero$.

بدي قيم s التي تجعل

$\boxed{s=\infty} \longrightarrow H(\infty) = \frac{1}{\infty} = Zero$.

- poles :- $H(s) = \infty$.

بدي قيم s التي تجعل ، يعني المقام = صفر

$1+9s = Zero$

$\boxed{s = \frac{-1}{9}}$

② :- $H(s) = \frac{3}{s(s+4)(s-1)}$ و find Zeros and poles :-

- Zeros :- $H(s) = Zero$.

$\boxed{s=\infty}$

- poles :- $H(s) = \infty$.

$\boxed{s = Zero}$

$s+4 = Zero$ و $\boxed{s=-4}$

$s-1 = Zero$ و $\boxed{s=1}$

- $H(s) = \frac{V_o(s)}{V_{in}(s)} \longrightarrow$ [Voltage gain]

$H(s) = \frac{I_o(s)}{I_{in}(s)} \longrightarrow$ [current gain]

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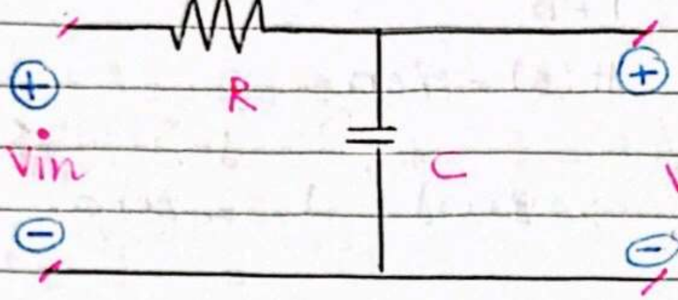
Q :- Find the voltage gain :-



- by voltage division :-

$$V_o = V_{in} \times \frac{\frac{1}{cs}}{\frac{1}{cs} + R}$$ [in frequency domain]

- so :- $H(s) = \frac{V_o(s)}{V_{in}(s)} = \frac{1}{1+scR}$

- so :- Zeros :- $H(s) = \text{Zero}$, $s = \infty$.

poles :- $H(s) = \infty$,

$1 + scR = \text{Zero}$

$s = \frac{-1}{cR}$.

∴ Note :-

$H(s) = \infty$ → cut-off frequency

or critical frequency

- Bode plot :- is the sketch of the phase and magnitude of a given transfer function [H(s)] as a function of [W].

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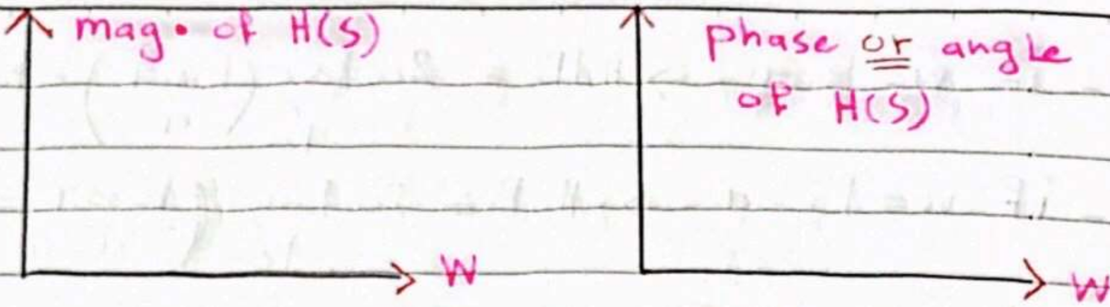


① :- if $H(s) = \left[1+\frac{s}{a}\right]$ و plot magnitude and phase Bode plot :-

- $H(jw) = \left[1 + \frac{jw}{a}\right]$.

- $|H(jw)| = \sqrt{1^2 + \left(\frac{jw}{a}\right)^2} = \sqrt{1 + \frac{w^2}{a^2}}$.

magnitude

∴ Note :- $|H(jw)|$ in dB.

$HdB = 20 \log_{10} |H(jw)|$.

so :- $HdB = 20 \log_{10} \sqrt{1 + \frac{w^2}{a^2}}$.

so :- there are three cases :-

1- $w \ll a$ و $HdB = 20 \log_{10} 1 = \text{Zero dB}$.

2- $w = a$ و $HdB = 20 \log_{10} \sqrt{2} = 3\,dB$.

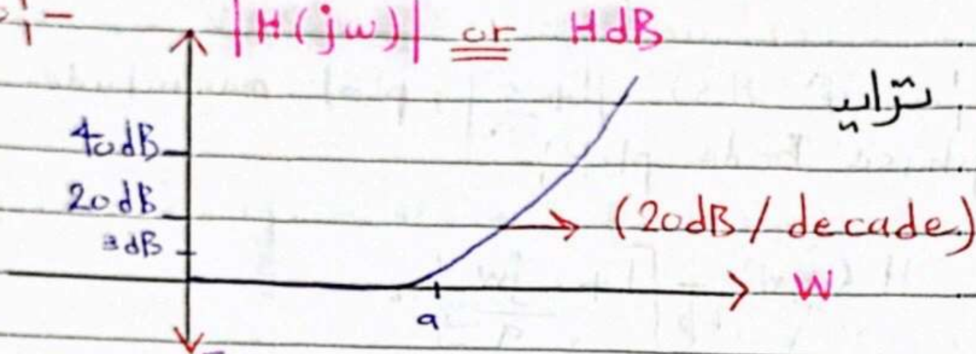
3- $w \gg a$ و $HdB = 20 \log_{10} \frac{w}{a} =$

so :- if $w = 10a$ →

$HdB = 20 \log_{10} \left(\frac{10\cancel{a}}{\cancel{a}}\right) = 20\,dB$.

- if $w = 100a \longrightarrow H_{dB} = 20\log_{10}\left(\frac{100a}{a}\right) = 40\,dB$.
- if $w = 1000a \longrightarrow H_{dB} = 20\log_{10}\left(\frac{1000a}{a}\right) = 60\,dB$.

sol:-

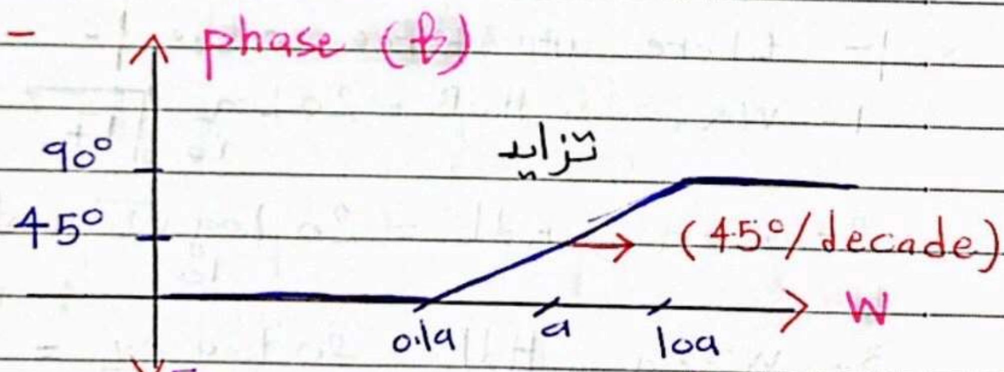


[The magnitude of H(s)]

- $\text{phase}\,H(jw) = \tan^{-1}\frac{w}{a}$.

sol:- 1- $w = a \longrightarrow \theta = \tan^{-1}(1) = 45^\circ$.
2- $w \gg a \longrightarrow \theta = \tan^{-1}(\infty) = 90^\circ$.
3- $w \ll a \longrightarrow \theta = \tan^{-1}(\text{Zero}) = \text{Zero}$.

sol:-



[The phase of H(S)]

إعداد:-م.سجى البزايعه

Q :- if $H(s) = \frac{s+10}{s}$, plot magnitude and phase Bode plot :-

- $H(s) = \frac{s}{s} + \frac{10}{s} = 1 + \frac{10}{s}$.

- $H(j\omega) = 1 + \frac{10}{j\omega} = 1 - \frac{j10}{\omega}$.

- $|H(j\omega)| = \left|1 - \frac{j10}{\omega}\right| = \sqrt{1 + \frac{10^2}{\omega^2}}$.

magnitude ←

- $H_{dB} = 20 \log_{10}\left[\sqrt{1+\frac{100}{\omega^2}}\right]$ dB .

so :- there are three cases :-

1- $\omega \gg 10 \rightarrow H_{dB} = 20 \log(1) =$ Zero dB .

2- $\omega = 10 \rightarrow H_{dB} = 20 \log\sqrt{2} = 3$ dB .

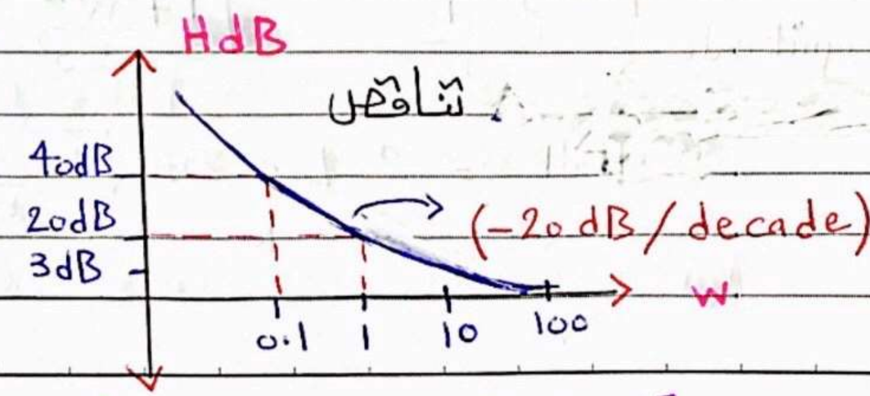
3- $\omega \ll 10 \rightarrow H_{dB} = 20 \log \frac{10}{\omega}$

so :-

- $\omega = 0.1 \times 10 = 1 \rightarrow$
$H_{dB} = 20 \log(10) = 20$ dB .

- $\omega = 0.01 \times 10 = 0.1 \rightarrow$
$H_{dB} = 20 \log(100) = 40$ dB .

so :-



[The magnitude of H(S)]

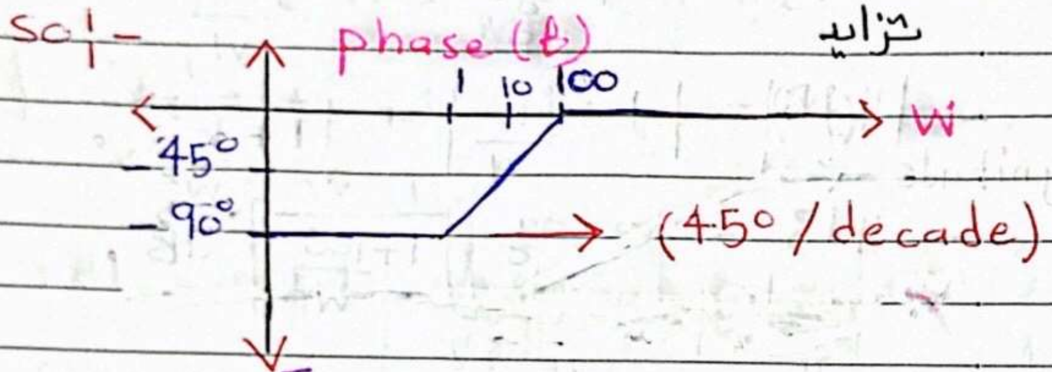
- phase $H(jw) = -\tan^{-1}\dfrac{10}{w}$.

sol:- 1- $w = 10 \longrightarrow \theta = -\tan^{-1}(1) = -45°$.

2- $w \ll 10 \longrightarrow \theta = -\tan^{-1}(\infty) = 90°$.

3- $w \gg 10 \longrightarrow \theta = -\tan^{-1}(\text{zero}) = \text{zero}$.

sol:-



[The phase of H(s)]

Q:- if $H(s) = 50 + s$, plot the magnitude and the phase Bode plot :-

- $H(s) = 50 + s = 50\left(1 + \dfrac{s}{50}\right)$.

- $H(jw) = 50\left(1 + \dfrac{jw}{50}\right)$.

- $|H(jw)| = 50\sqrt{1 + \dfrac{w^2}{50^2}}$. ← magnitude

- $H\,dB = 20\log_{10} 50\sqrt{1 + \dfrac{w^2}{50^2}}\ dB$.

sol:- there are three cases:-

1- $W \ll 50 \rightarrow HdB = 20 \log 50 = 34dB$.

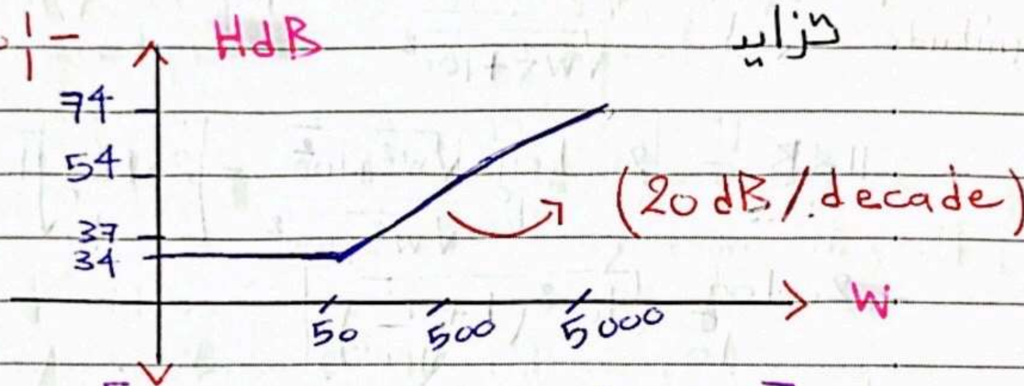
2- $W = 50 \rightarrow HdB = 20 \log \sqrt{2} \times 50 = 37dB$.

3- $W \gg 50 \rightarrow HdB = 20 \log W$

↳ sol:-

- $W = 500 \rightarrow HdB = 54dB$.
- $W = 5000 \rightarrow HdB = 74dB$.

sol:-



[The magnitude of H(S)]

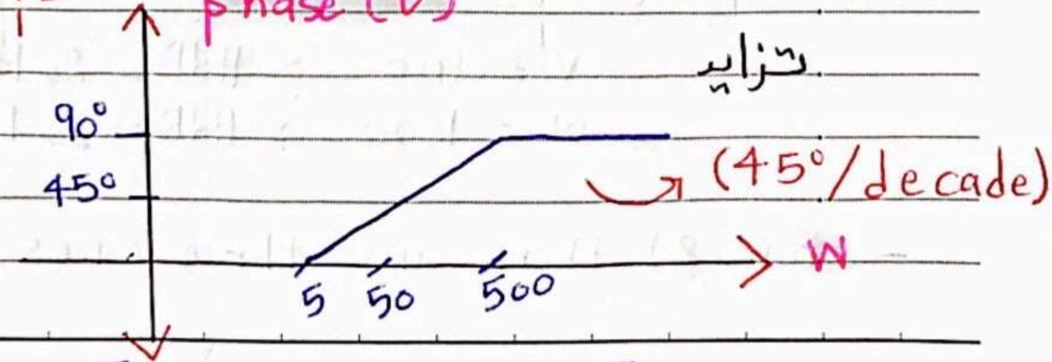
- phase $H(jw) = \theta = \tan^{-1}\frac{w}{50}$.

sol:- 1- $W = 50 \rightarrow \theta = \tan^{-1}(1) = 45°$.

2- $W \ll 50 \rightarrow \theta = \tan^{-1}(zero) = Zero$.

3- $W \gg 50 \rightarrow \theta = \tan^{-1}(\infty) = 90°$.

sol:-



[The phase of H(s)]

إعداد:-م.سجى البزايعه

Q :- if $H(s) = \left[\frac{s+10}{s+100}\right]$, plot the magnitude and the phase Bode plot :-

- $H(jw) = \frac{jw+10}{jw+100}$.

- $|H(jw)| = \frac{\sqrt{w^2+10^2}}{\sqrt{w^2+100^2}}$.

magnitude

- $H_{dB} = 20 \log_{10} \frac{\sqrt{w^2+100}}{\sqrt{w^2+100^2}} = \left[20 \log_{10} \sqrt{10^2\left(1+\frac{w^2}{10^2}\right)} - 20 \log_{10} \sqrt{100^2\left(1+\frac{w^2}{100^2}\right)}\right]$

$= \left[\underbrace{20 \log_{10} 10 \sqrt{1+\frac{w^2}{10^2}}}_{1} - \underbrace{20 \log_{10} 100 \sqrt{1+\frac{w^2}{100^2}}}_{2}\right]$

- For (1) there are three cases :-

1- $w \ll 10 \rightarrow H_{dB} = 20 \log 10 = 20\,dB$.

2- $w = 10 \rightarrow H_{dB} = 20 \log 10\sqrt{2} = 23\,dB$.

3- $w \gg 10 \rightarrow H_{dB} = 20 \log w$

so :-

- $w = 100 \rightarrow H_{dB} = 20 \log 100 = 40\,dB$.
- $w = 1000 \rightarrow H_{dB} = 20 \log 1000 = 60\,dB$.

- For (2) there are three cases :-

1- $w \ll 100 \rightarrow H_{dB} = 20 \log 100 = 40\,dB$.

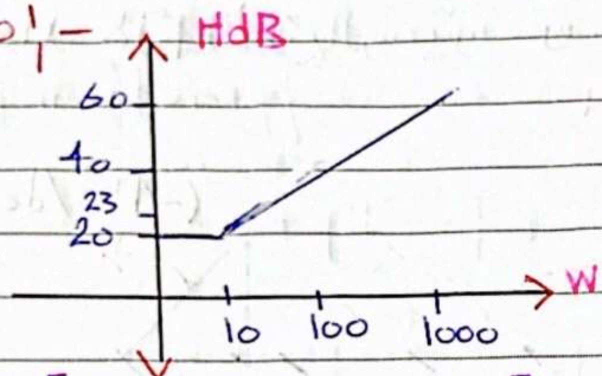
2- $w = 100 \rightarrow H_{dB} = 20 \log 100\sqrt{2} = 43\,dB$.

3- $w \gg 100 \rightarrow H_{dB} = 20 \log w$

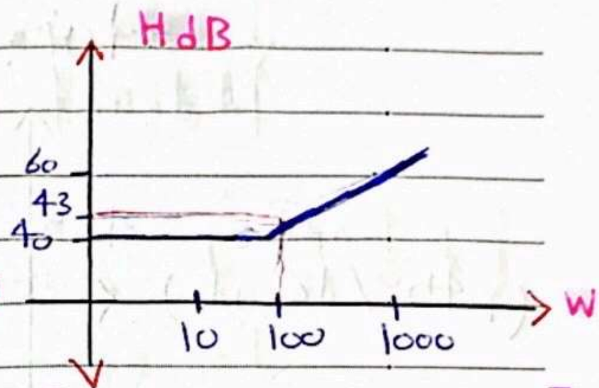
↳ Sol:-

- $w = 100 \rightarrow H_{dB} = 20 \log 100 = 40\,dB$.
- $w = 1000 \rightarrow H_{dB} = 20 \log 1000 = 60\,dB$.

Sol:-

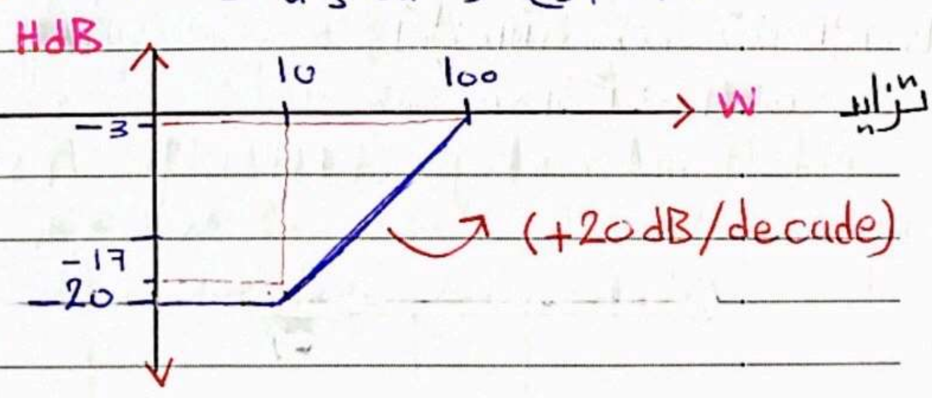


[The magnitude of (1)]



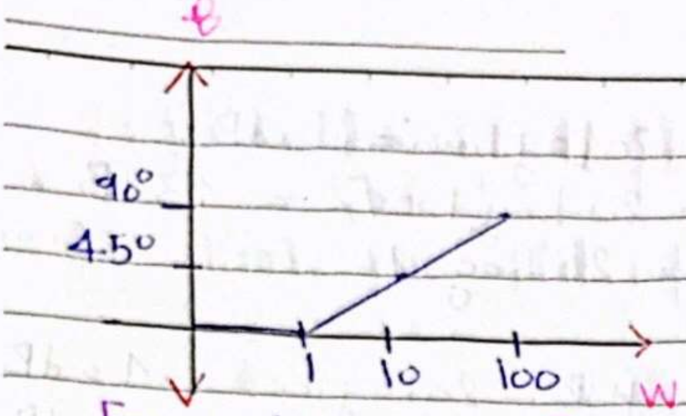
[The magnitude of (2)]

- هلأ لازم أطرح الرسمتين إلي فوق من بعض :-

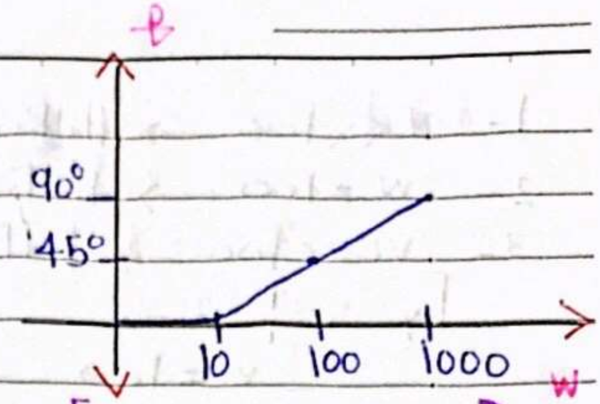


- θ = phase of $H(jw) = \tan^{-1}\frac{w}{10}$ و $\tan^{-1}\frac{w}{100}$

$$\theta = \left[\tan^{-1}\frac{w}{10} - \tan^{-1}\frac{w}{100}\right].$$

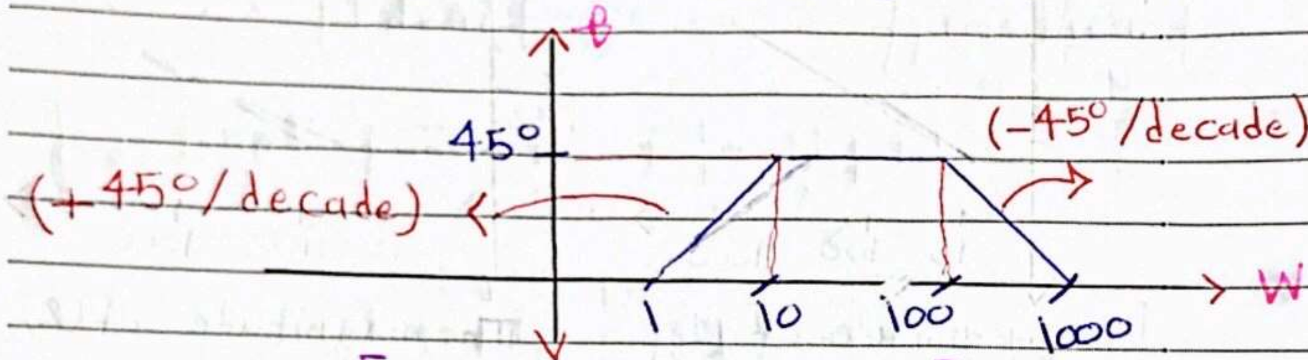


[The phase of (1)]



[The phase of (2)]

- هنا لازم نطرح الرسمتين من بعض !



[The phase of H(s)]

لأن الله سوف يحتضن أرواحنا
وستكون دائماً في أمان

- Filters :- used to reject or select a band of frequency. [noise]

- By depending on circuit components, there are two types of filters :-

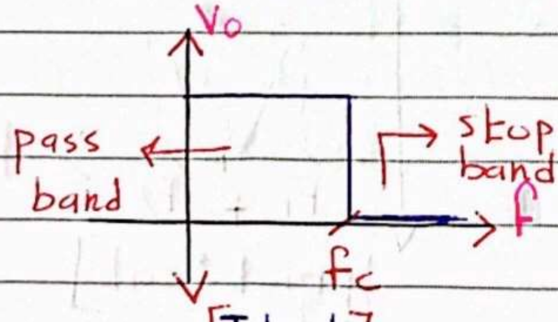
1- Active filters :- [Rc, RL, RLc] with op-Amp.

2- passive filters :- [Rc, RL, RLc].

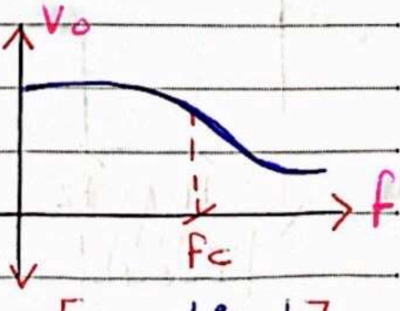
- By depending on frequency band, there are four types of filters :-

1- Low pass filter (Lpf).
2- High pass filter (Hpf).
3- Band pass filter (Bpf).
4- Band stop filter (Bsf).

[1] Low pass Filter :- (LpF)



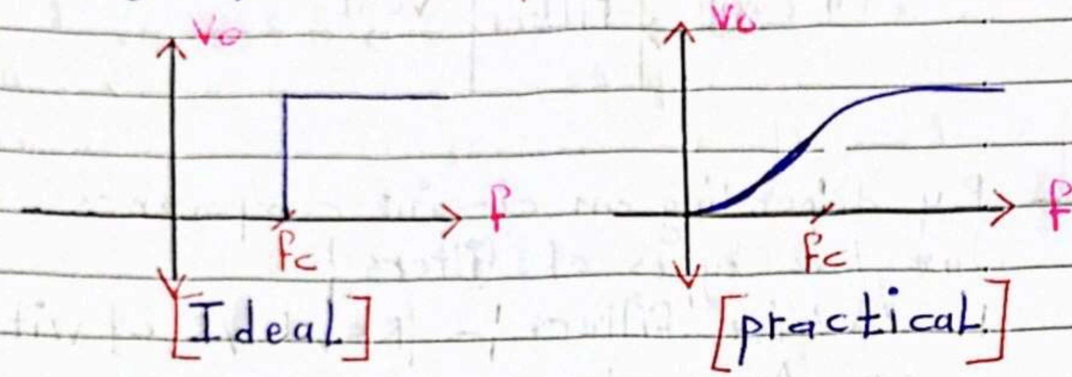
[Ideal]



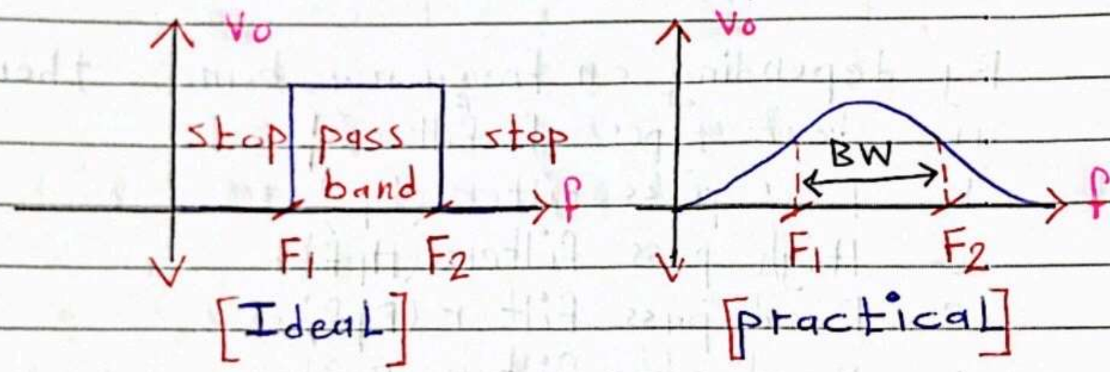
[practical]

Fc :- cut-off frequency.

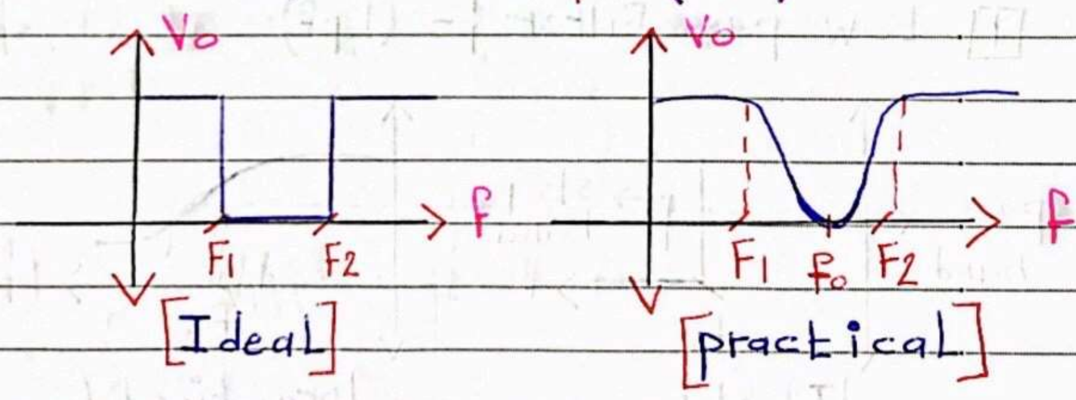
☐2 High pass filter :- (HPF)



☐3 Band pass filter :- (BPF)

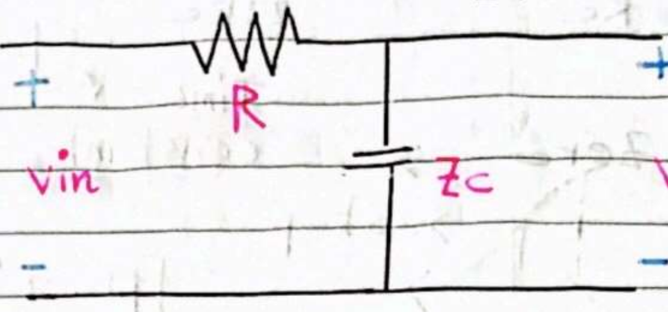


☐4 Band stop filter :- (BSF)



إعداد:-م.سجى البزايعه

1- RC circuit :- [LPF]



- $V_o = \frac{v_{in} Z_c}{Z_c + R}$ [voltage division].

- A_V = voltage gain $= \frac{V_o}{v_{in}} = \frac{\frac{1}{j\omega c}}{\frac{1}{j\omega c} + R}$

$= \frac{1}{1 + j\omega RC} \rightarrow$ [Transfer Function]. $\rightarrow H(j\omega)$

- $|H(j\omega)| = \sqrt{\frac{1}{1 + R^2 \omega^2 c^2}} = A_V = \frac{V_o}{v_{in}}$.

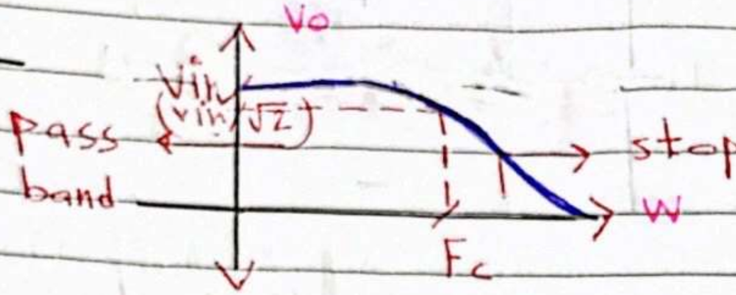
magnitude

- 1- At $\omega = 0 \rightarrow A_V = H(j\omega) = 1 \rightarrow$
$V_o = v_{in} \rightarrow X_c = \infty$ [O.C].
2- At $\omega = \infty \rightarrow A_V = H(j\omega) = $ Zero $\rightarrow$
$V_o =$ Zero $\rightarrow X_c =$ Zero [S.C].
3- At $\omega = \omega_c = \frac{1}{RC} \rightarrow A_V = H(j\omega) =$
$\frac{1}{\sqrt{2}} \rightarrow V_o = \frac{1}{\sqrt{2}} v_{in} \rightarrow X_c = R$.

إعداد:-م.سجى البزايعه

sol:- $w_c = \frac{1}{RC}$, $f_c = \frac{1}{2\pi RC}$, $\tau = RC$.

Time constant

- 

[practical]

- $AV = \frac{1}{1+jw_cR} \times \left(\frac{1-jw_cR}{1-jw_cR}\right)$

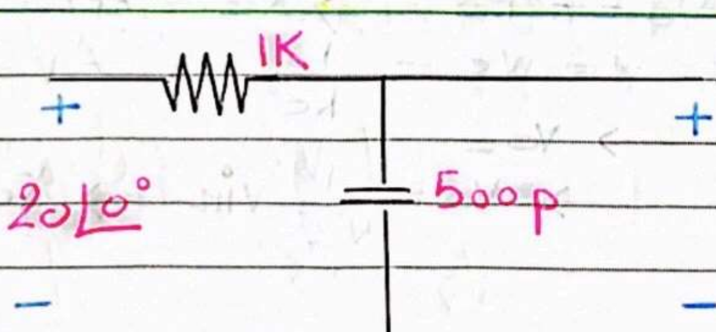
$$= \frac{1-jw_cR}{1+w^2c^2R^2} .$$

- $|AV| = \frac{1}{\sqrt{1+\frac{R^2}{X_c^2}}}$.

- phase angle $= \theta = -\tan^{-1}\frac{R}{X_c} = \tan^{-1}(wRC)$

sol:- At $f = f_c \rightarrow X_c = R \rightarrow$

$AV = \frac{1}{\sqrt{2}} \rightarrow V_o = \frac{v_{in}}{\sqrt{2}}$.

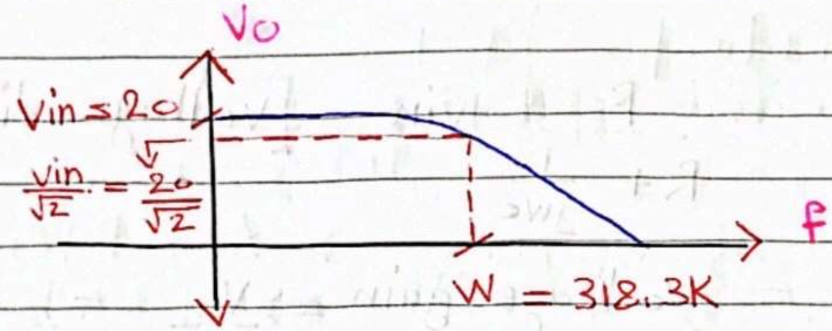
Q:- 

1- Draw Frequency response For vo :-

(vo versus Fo) :-

LPF $\rightarrow$ $W_c = \frac{1}{RC}$ $\rightarrow$ $f_c = \frac{1}{2\pi RC}$

$= \frac{1}{2\pi \times 1K \times 500 \times 10^{-12}} = 318.3K\ HZ.$



2- determine vo at f = 100 KHz, f = 1 M.HZ :-

$V_o = \frac{V_{in}}{\sqrt{1+w^2c^2R^2}}.$

At f = 100 KHZ , W = 2πF ,

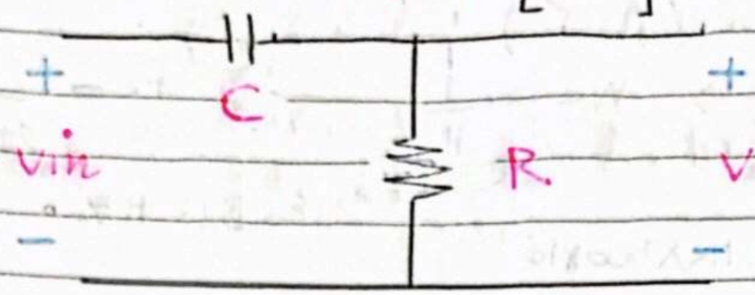
$V_o = \frac{20}{\sqrt{1+(2\pi \times 100K)^2 \times (1K)^2 \times (500p)^2}} = 19.08V.$

At f = 1 MHZ :-

$V_o = \frac{20}{\sqrt{1+(2\pi \times 1M)^2 \times (1K)^2 \times (500p)^2}} = 6.06V.$

إعداد:-م.سجى البزايعه

Q:- Rc circuit :- [HpF]



- $V_o = \dfrac{R}{R + \frac{1}{jwc}} \, v_{in}$ [voltage division].

- A_v = voltage gain $= \dfrac{V_o}{v_{in}} = \dfrac{R}{R + \frac{1}{jwc}}$

$\dfrac{jwcR}{1 + jwcR} = \dfrac{1}{1 - \frac{j}{wcR}} \longrightarrow$ [Transfer Function] $\longrightarrow H(jw)$

- $|H(jw)| = \sqrt{\dfrac{1}{1 - \frac{1}{w^2c^2R^2}}}$

- 1- At $w = zero \longrightarrow A_v = H(jw) = Zero$
  $\longrightarrow V_o = Zero \longrightarrow X_c = \dfrac{1}{wc} = \infty$
  [o.c].

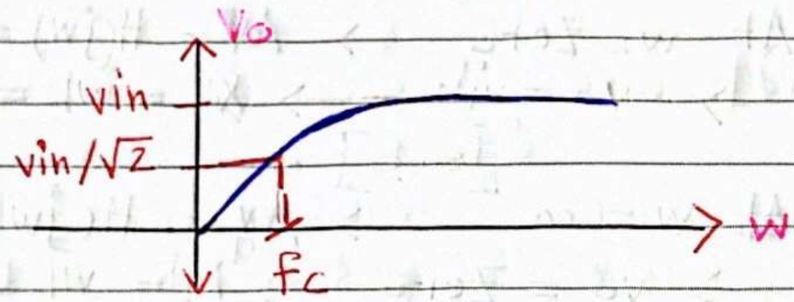
  2- At $w = \infty \longrightarrow A_v = H(jw) = 1$
  $\longrightarrow V_o = V_{in} \longrightarrow X_c = \dfrac{1}{wc} = zero$
  [s.c]

- $H(jw) = A_V \Big|_{X_c = \frac{1}{wc}} = \dfrac{1}{1 - \frac{jX_c}{R}}$.

- $|AV| = \dfrac{1}{\sqrt{1+\dfrac{Xc^2}{R^2}}}$.

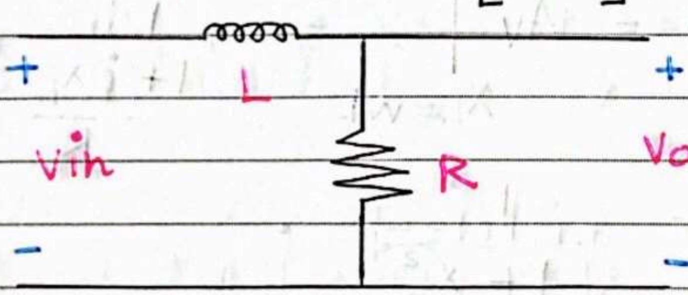
- phase angle = $\phi = \tan^{-1}\dfrac{Xc}{R} = \tan^{-1}\dfrac{1}{wcR}$.

so :- At $f = fc \longrightarrow Xc = R \longrightarrow$
$Av = \dfrac{1}{\sqrt{2}} \longrightarrow vo = \dfrac{vin}{\sqrt{2}}$.

- 

[practical]

②:- RL circuit :- [LPF]



- $Vo = \dfrac{R}{R+jwL}\,vin = \dfrac{1}{1+\dfrac{jwL}{R}}\,vin$

[voltage division] .

إعداد:-م.سجى البزايعه

- AV = voltage gain $= \frac{V_o}{V_{in}} = \frac{1}{1+\frac{jwL}{R}}$.

$\longrightarrow$ [Transfer Function] $\longrightarrow H(jw)$.

- $|H(jw)| = \sqrt{\frac{1}{1-\frac{w^2L^2}{R^2}}}$.

- 1- At $w =$ Zero $\longrightarrow AV = H(jw) = 1$

$\longrightarrow V_o = V_{in} \longrightarrow X_L = wL =$ Zero

[S.C] .

2- At $w = \infty \longrightarrow AV = H(jw) =$ Zero

$\longrightarrow V_o =$ Zero $\longrightarrow X_L = wL = \infty$

[O.C] .

- $H(jw) = AV \Big|_{X_L = wL} = \frac{1}{1+\frac{jX_L}{R}}$.

- $|AV| = \frac{1}{\sqrt{1-\frac{X_L^2}{R^2}}}$.

- phase angle $= \theta = \tan^{-1}\left(\frac{-wL}{R}\right) =$

$\tan^{-1}\left(\frac{-XL}{R}\right)$.

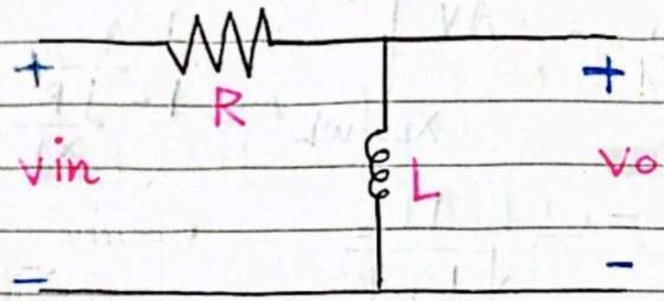
so :-

At $f = f_c \longrightarrow X_L = R \longrightarrow A_v = \dfrac{1}{\sqrt{2}}$

$\longrightarrow v_o = \dfrac{v_{in}}{\sqrt{2}}$.

∴ Note :- $\tau = RC$ / $\tau = \dfrac{L}{R}$.

① :- RL circuit :- [HPF]



– $v_o = \dfrac{jwL}{R + jwL} v_{in} = \dfrac{1}{1 - j\dfrac{R}{wL}} v_{in}$

[voltage division] .

– $A_V = \text{voltage gain} = \dfrac{v_o}{v_{in}} = \dfrac{1}{1 - j\dfrac{R}{wL}}$.

$\longrightarrow$ [Transfer Function] $\longrightarrow H(jw)$.

– $|H(jw)| = \sqrt{\dfrac{1}{1 + \dfrac{R^2}{w^2L^2}}}$.

إعداد:-م.سجى البزايعه

- 1- At $w = zero \longrightarrow Av = H(jw) = zero$
$\longrightarrow v_o = zero \longrightarrow X_L = zero$
[s.c] .

2- At $w = \infty \longrightarrow Av = H(jw) = 1$
$\longrightarrow V_o = v_{in} \longrightarrow X_L = \infty$
[o.c] .

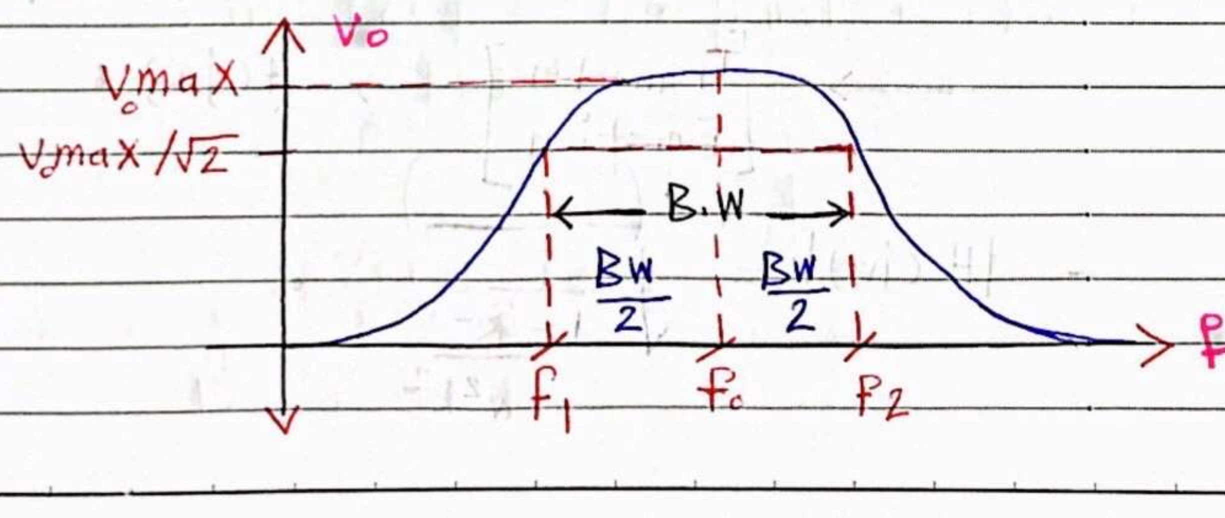
- $H(jw) = Av \Big|_{X_L = wL} = \dfrac{1}{1 - j\dfrac{R}{X_L}}$.

- $|Av| = \dfrac{1}{\sqrt{1 + \dfrac{R^2}{X_L^2}}}$.

- phase angle $= \theta = \tan^{-1} \dfrac{R}{X_L} = \tan^{-1} \dfrac{R}{wL}$.

sol:- At $f = f_c \longrightarrow X_L = R \longrightarrow$
$Av = \dfrac{1}{\sqrt{2}} \longrightarrow V_o = \dfrac{v_{in}}{\sqrt{2}}$.

- Band pass Filter :-



F_1 و F_2 :- corner Frequency.
F_o :- center Frequency.
BW :- Bandwidth $\longrightarrow$ $BW = [F_2 - F_1]$.

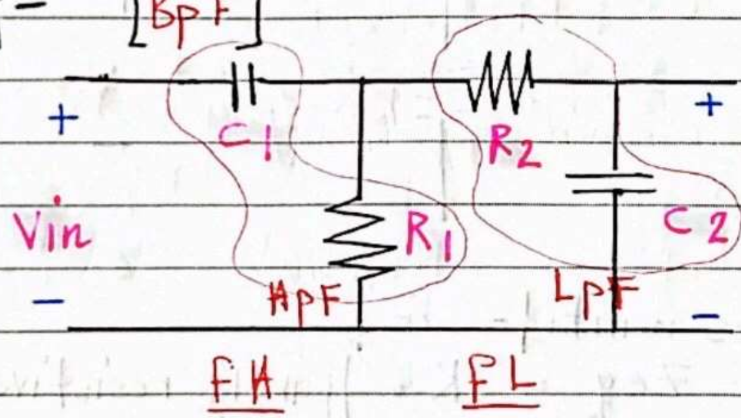
so :- $V_o\Big|_{F=F_1/F_2} = \dfrac{V_{o\,max}}{\sqrt{2}}$.

$V_o\Big|_{F=F_o} = V_{o\,max}$.

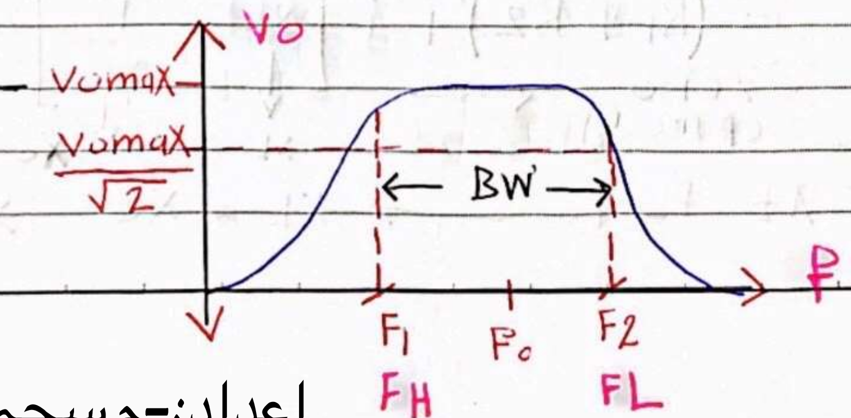
$F_o = F_1 + \dfrac{BW}{2} = F_2 - \dfrac{BW}{2}$.

$F_o = \dfrac{F_1 + F_2}{2}$.

② :- [BPF]



– BPF $\longrightarrow$ LPF + HPF.



إعداد:-م.سجى البزايعه

- FL > FH.

so :- $F_1 < F_o < F_2$.

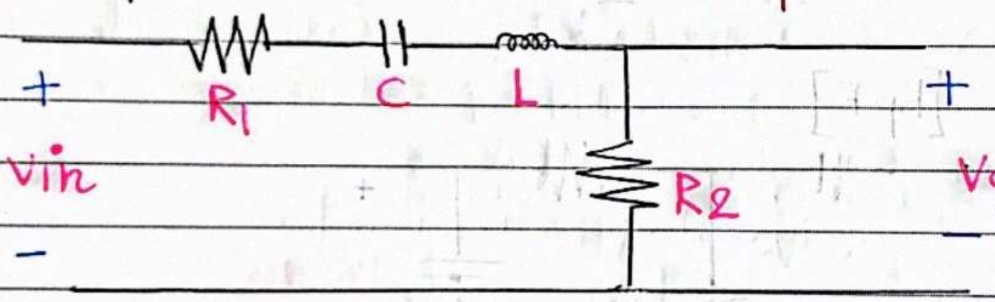
- $F_o = F_1 + \frac{B.W}{2} = F_2 - \frac{B.W}{2}$.

- $F_o = \frac{F_1 + F_2}{2}$ و $F_2 - F_1 = B.W$.

- $F_L = \frac{1}{2\pi R_2 C_2}$.

$F_H = \frac{1}{2\pi R_1 C_1}$.

① :- series RLC circuit :-



- At resonant :- F_o

$Z_{in} = Z_{eq} = R$. [purely resistive Load]

$Z_{eq} = R_1 + jwL + \frac{1}{jwC} + R_2$

$= \underbrace{(R_1 + R_2)}_{\text{(pure R)}} + \underbrace{j\left[\underset{X_L}{wL} - \underset{X_C}{\frac{1}{wC}}\right]}_{\text{Zero}}$

- so :-

1- At $F = F_o \longrightarrow X_L = X_C \longrightarrow$

$$\omega L - \frac{1}{\omega c} = Zero \quad , \quad \omega L = \frac{1}{\omega c} \longrightarrow$$

$$X_L = X_c \longrightarrow \omega_o = \frac{1}{\sqrt{Lc}} \longrightarrow$$

$$F_o = \frac{1}{2\pi\sqrt{Lc}} .$$

$$sol:- \quad V_{o\,max} = V_o \Big|_{F=F_o} = \frac{R_2}{R_1+R_2} \, vin$$

[voltage division].

$$- \text{Quality Factor} = Q = \frac{\text{total stored energy}}{\text{total energy Lost}}$$

$$= \frac{energy\,(Lc)}{energy\,(R_{total})} = \frac{P(\omega L + \cancel{\omega c})}{P R_{total}} = \frac{X_L}{R_{eq}}$$

$$= \frac{\omega_o L}{R_1+R_2} = \frac{2\pi F_o L}{R_1+R_2} .$$

$$sol:- \quad B.W = \frac{F_o}{Q} = \frac{R_1+R_2}{2\pi L} \; (HZ).$$

or

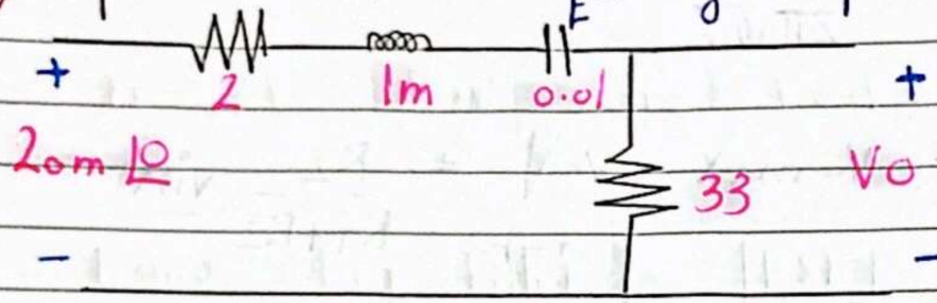
$$B.W = \frac{\omega_o}{Q} = \frac{\omega_o}{\frac{\omega_o L}{R}} = \frac{R}{L} \; (rad/s).$$

∴ Note :-

$\varphi \uparrow \longrightarrow BW \downarrow$.

$\varphi \downarrow \longrightarrow BW \uparrow$.

φ :- Draw the Frequency response :-



— $f_o = \dfrac{1}{2\pi\sqrt{LC}} = \dfrac{1}{2\pi\sqrt{0.01 \times 33}} = 50.33\ KHZ$.

— $V_o\ max = \dfrac{R_1}{R_1 + R_2} V_{in}$

$= \dfrac{33}{33+2} \times 20m = 18.85mV$.

— $\varphi = \dfrac{W_o L}{R_1 + R_2} = \dfrac{2\pi f_o}{R_1 + R_2} = \dfrac{2\pi \times 50.33K}{33 + 2}$

$= 9.035$.

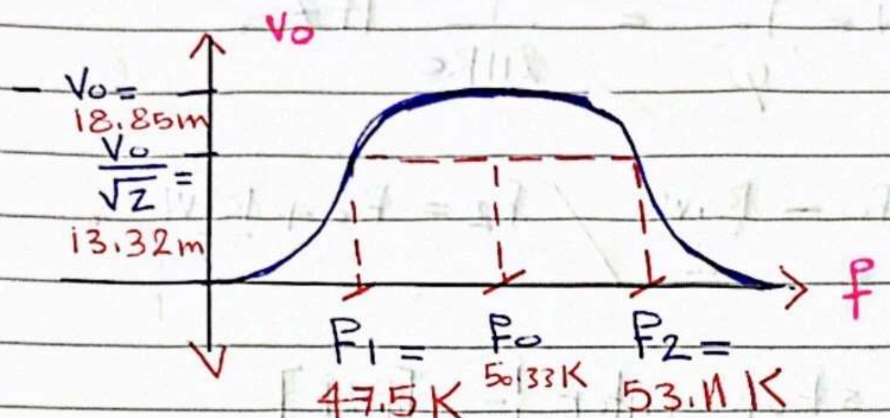
— $B.W = \dfrac{f_o}{\varphi} = \dfrac{50.33K}{9.035} = 5.57\ KHZ$.

— $f_L = f_o - \dfrac{B.W}{2} = 50.33K - \dfrac{5.57K}{2}$

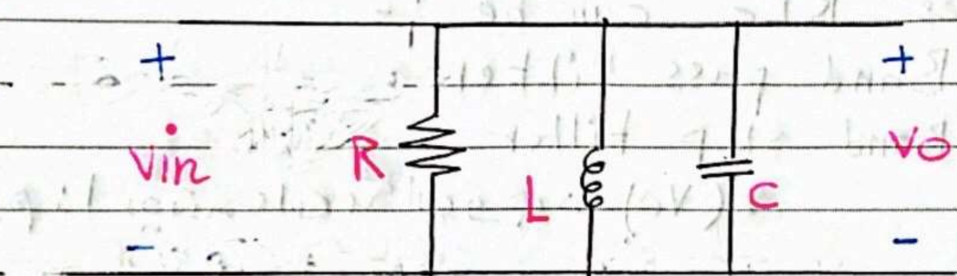
$= 47.5\ KHZ$.

إعداد:-م.سجى البزايعه

- $f_2 = f_o + \frac{B.W}{2} = 50.33K + \frac{5.57K}{2}$
$= 53.11\ KHZ$.



Q) :- parallel RLC circuit :-



- $Z_{eq} = Z_{in} = R // jwL // \frac{1}{jwc} = \underbrace{\quad}_{Real} + j\underbrace{X}_{Img}$

- At resonant frequency (f_o) , $f = f_o$,
$X_{eq} = zero \longrightarrow w_o = \frac{1}{\sqrt{Lc}} \longrightarrow$

$f_o = \frac{1}{2\pi\sqrt{Lc}}$.

- Quality factor $= Q = w_o R c$.

إعداد:-م.سجى البزايعه

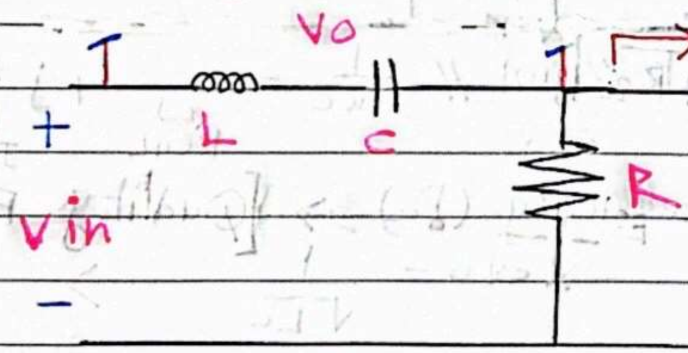
- $B.W = \frac{w_o}{\varphi} = \frac{1}{Rc}$ (rad/s).

or $B.W = \frac{F_o}{\varphi} = \frac{1}{2\pi Rc}$ HZ.

- $F_1 = F_o - \frac{B.W}{2}$ / $F_2 = F_o + \frac{B.W}{2}$.

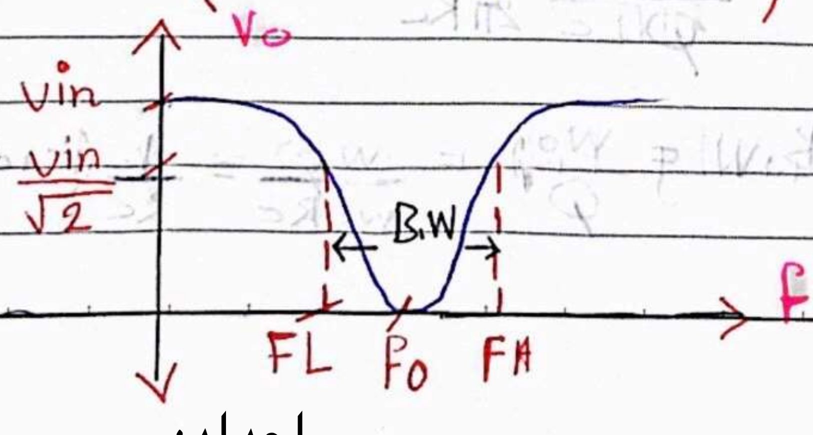
- Band stop Filter :- [BSF]

∴ Note :-
series RLC can be :-
1- Band pass filter.
or 2- Band stop Filter.
وهذا يعتمد على مكان وجود (Vo).



→ Voutput is taken from C/L.

(Band stop Filter)



إعداد:-م.سجى البزايعه

- $F_L < F_H$.

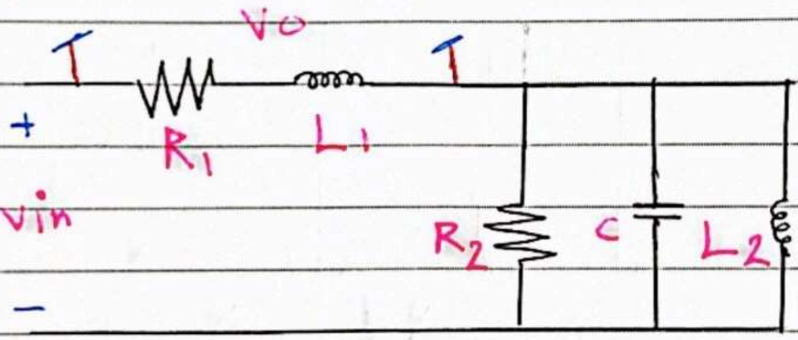
- $F_L = F_o - \frac{B.W}{2}$ / $F_H = F_o + \frac{B.W}{2}$.

- $B.W = \frac{R}{2\pi L}$ HZ $\Big|_{f=f_o}$.

or $B.W = \frac{R}{L}$ rad/s .

or BSF can be [HPF + LPF] parallel

والأهم ننتبه للمكان الذي أخذ منه Vo .



(Band stop Filter)

نسألك يا الله أن تكون
الأيام حنونة على قلوبنا ♡