Circuits II Notebook
Dr. Iyad Abulfailat

By . Isra' Jamil

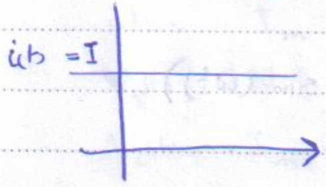
بأفكارنا_نُبدع

1st & 2nd week

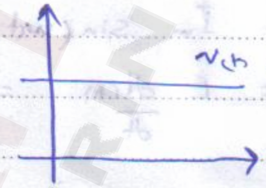
No. Lecture 1.

15-9-2014
- Monday

** cct analysis. (Review)



DC - current



DC - voltage

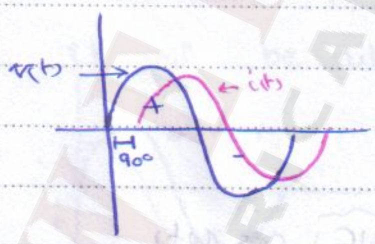
$p(t) \equiv$ instantanuous power $= V \cdot I = v(t) \cdot i(t)$

→ AC cct analysis

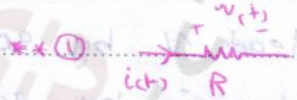
$v(t)$ & $i(t)$ are time varrying function

- $v(t) = V_m \sin(\omega t)$
- $i(t) = I_m \sin(\omega t + \theta)$

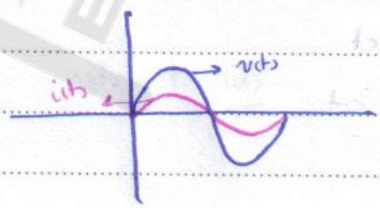
∴ where $\omega \equiv$ Angular freq (rad/s) $= 2\pi f$



** ①



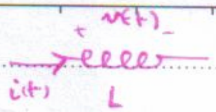
$i(t) = \frac{v(t)}{R} = \frac{V_m}{R} \sin(\omega t) = I_m \sin(\omega t)$



v & i → in phase

No.

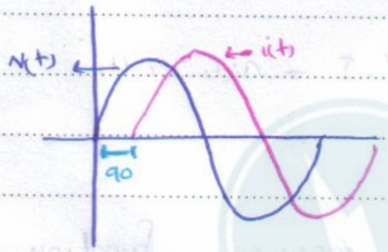
** ②



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

$v(t) = L \frac{di(t)}{dt} = L \frac{d}{dt}\left(I_m \sin(\omega t)\right)$

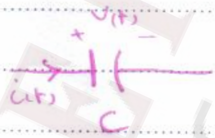
$= I_m (\omega L) \cos \omega t$



⇒ i lags v by 90°
OR v leads i

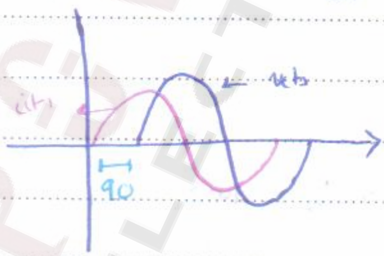
@ low freq $\xrightarrow{\text{acts as}}$ short cct
@ high freq $\xrightarrow{\text{acts as}}$ open cct

** ③



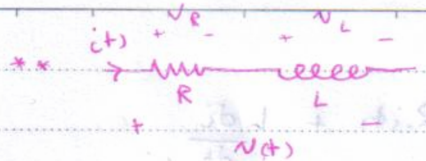
$v(t) = V_m \sin(\omega t)$

$i(t) = C \frac{dV_c}{dt} = V_m (\omega C) \cos(\omega t)$



⇒ i leads v by 90°
OR v lags i by 90°

@ low freq ⟶ open cct
@ high freq ⟶ short cct

** 

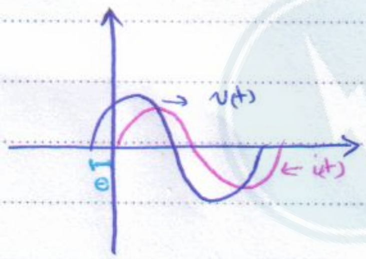
$i(t) = I_m \sin \omega(t)$

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

$v_L(t) = I_m \omega L \cos(\omega t)$

$v_{tot} = V_{R_m} \sin(\omega t) + V_{C_m} \cos(\omega t)$

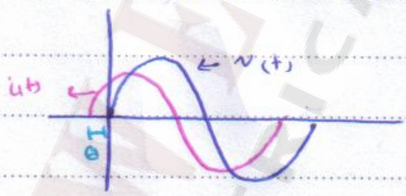
$= V \sin(\omega t + \theta)$



⇒ i lags v by θ

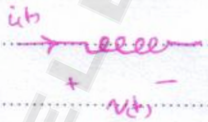
** if we have R & C

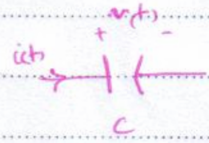
it will be like:



⇒ i leads v by θ

*** Remember

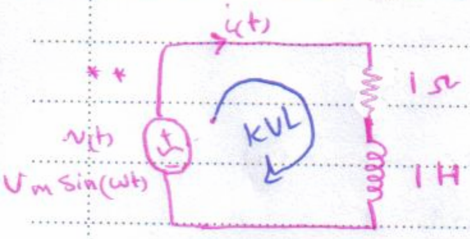




$v(t) = L \frac{di(t)}{dt}$

$i(t) = C \frac{dV_c}{dt}$

No. ....

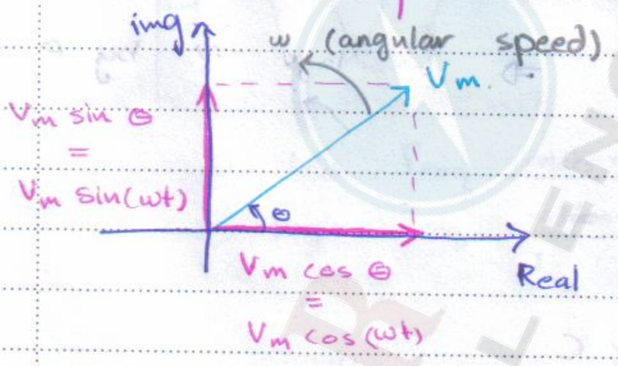


$$v(t) = R.i(t) + L\frac{di}{dt}$$

$$V_m \sin(\omega t) = R.i(t) + L\frac{di}{dt}$$ ⟸ diff equ ?

∴ so ⇝ (convete) from time domain ⟶ (to) phasor domain (freq)

** Phasor representation

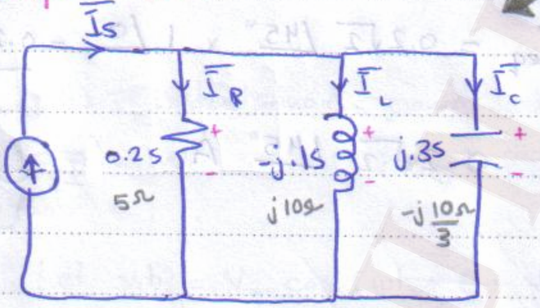


No. Lecture 3

22-9-2014
Monday.

> Capacitive $\frac{10}{3} < 10$ #
> Parallel → cct الاصغر هو اللي بتحكم بال
> series → الاكبر قيمة هو اللي بتتحكم

* example 10.15



$V = 1\angle 0°$ V

↓ same as

$V(t) = 1\cos(\omega t + 0)$ V

sol. by $\xrightarrow{KCL}$ $\overline{I_s} = \overline{I_R} + \overline{I_c}$

$Z_R = R \ (\Omega)$

$Y_R = \frac{1}{R} = G \ (S)$

$Z_L = j\omega L = +j X_L \ \Omega$

$Y_L = \frac{1}{Z_L} = \frac{1}{jX_L} = -j B_L \ S$] من الاشارات والوحدة بقدر احكم انها inductive Reactance.

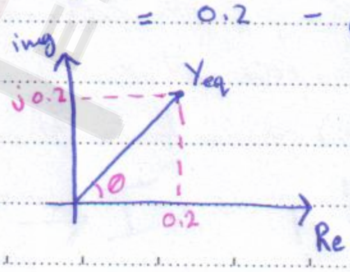
$Z_c = \frac{1}{j\omega} = -j X_c \ \Omega$

$Y_c = \frac{1}{-j\omega C} = +j B_c \ S$] capacitive Reactence

$\frac{1}{Z_{eq}} = \frac{1}{Z_R} + \frac{1}{Z_L} + \frac{1}{Z_c}$

$Y_{eq} = Y_R + Y_L + Y_c$

$= 0.2 - j0.1 + j0.3 = 0.2 + j0.2$ S



$Y_{eq} = 0.2\sqrt{2}\angle 45°$ S

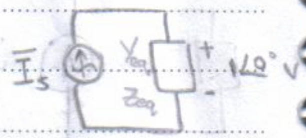
⟶

No.

$\leftarrow \quad Z_{eq} = \dfrac{1}{Y_{eq}} = \dfrac{1}{0.2\sqrt{2}\,\angle 45^\circ} = \dfrac{5}{2}\sqrt{2}\,\angle -45^\circ\ \Omega$

$\bar{I}_s = \dfrac{\bar{V}}{Z_{eq}} = \bar{V}\,Y_{eq} = 0.2\sqrt{2}\,\angle 45^\circ \times 1\angle 0^\circ = 0.2\sqrt{2}\,\angle 45^\circ\ A$

$= \dfrac{1\angle 0^\circ}{2.5\sqrt{2}\,\angle -45^\circ} = 0.2\sqrt{2}\,\angle 45^\circ\ A$



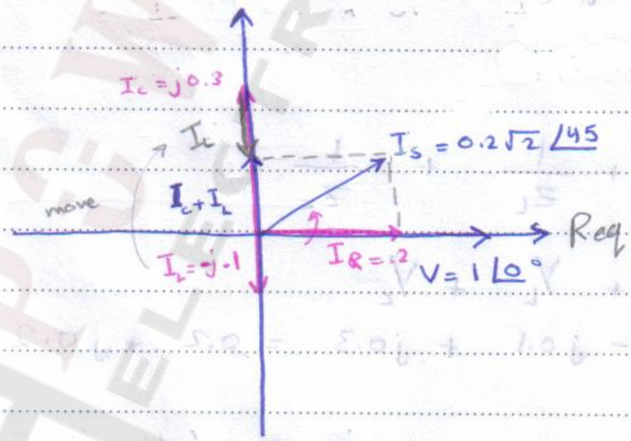
note that if $0^\circ < \theta < 90^\circ \longrightarrow$ capacitive
& if $\theta = 90^\circ \longrightarrow$ pure capacitive.) According to I_s

$\bar{I}_R = \dfrac{\bar{V}}{Z_R} = \dfrac{\bar{V}}{R} = \dfrac{1\angle 0^\circ}{5\angle 0^\circ} = 0.2\angle 0^\circ\ A$ (in phase)

$\bar{I}_L = \dfrac{\bar{V}}{Z_L} = \dfrac{1\angle 0^\circ}{10\angle 90^\circ} = 0.1\angle -90\ A = -j0.1\ A$

$\bar{I}_C = \dfrac{\bar{V}}{Z_C} = \dfrac{1\angle 0^\circ}{\frac{10}{3}\angle -90^\circ} = 0.3\angle 90^\circ\ A = j\,0.3\ A$

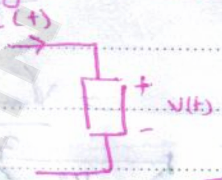
Review $\longrightarrow$ Lead & lag



$\leftarrow$ using sliding vectors in order to draw $\bar{I}_s$

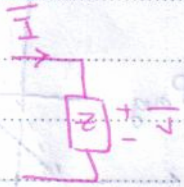
No.

** CH.11 "AC circuit Analysis" / Power.



$p(t) \equiv$ instentanuous power

AC/DC ← $p(t) = v(t) \times i(t)$



Let $v(t) = V_m \cos(\omega t + \theta)$ V

Let $i(t) = I_m \cos(\omega t + \phi)$ A

so $p(t) = v(t) \cdot i(t)$

$= V_m \cos(\omega t + \theta) \cdot I_m \cos(\omega t + \phi)$

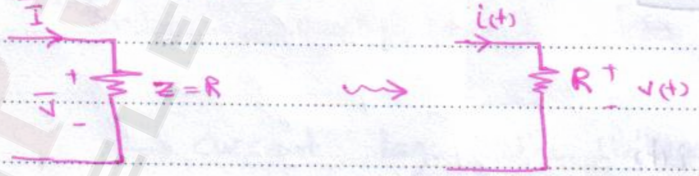
$= \frac{V_m I_m}{2} \left[\cos(\theta - \phi) + \cos(2\omega t + \theta + \phi)\right]$

$= \frac{V_m I_m}{2} \cos(\theta - \phi) + \frac{V_m I_m}{2} \cos(2\omega t + \underbrace{\theta + \phi}_{\beta})$

DC quentity, shift up or down (constant) — Peak value

► note that 1 cycle voltage $\xrightarrow[\text{me}]{\text{gives}}$ 2 cycles of power

**ex. Let $Z = R$ — Pure Resistive



$v(t) = V_m \cos(\omega t + \theta)$
$i(t) = I_m \cos(\omega t + \theta)$] because they are in phase

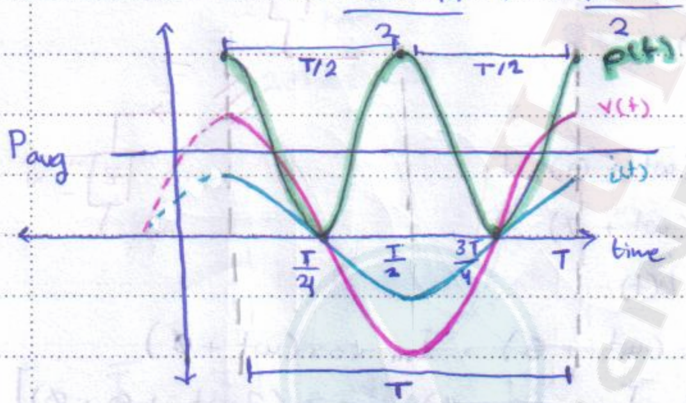
→ In phase ←

No. ....

$\leftarrow \quad p(t) = v(t) \cdot i(t)$

$= \frac{V_m I_m}{2}\left[\cos(0) + \cos(2\omega t + 2\theta)\right]$

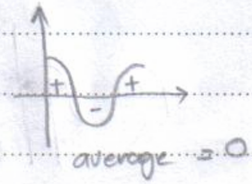
$= \frac{V_m I_m}{2} + \frac{V_m I_m}{2}\cos(2\omega t + 2\theta)$



peak جيب peak مع

power لحتى أطلع ال

* note : resistor ⟶ passive element (consume power)



$P \equiv$ average power

$$P = \frac{1}{T}\int_0^T v(t) \cdot i(t)\, dt$$

$$= \frac{1}{T}\int_0^T \frac{V_m I_m}{2}\, dt + \frac{1}{T}\int_0^T \frac{V_m I_m}{2}\cos(2\omega t + 2\theta)\, dt$$

(second term crossed out → 0)

$$\Rightarrow \boxed{P = \frac{I_m V_m}{2}}$$ if they are constant ?!

By ohm's low

$v(t) = R \cdot i(t)$

$\Rightarrow i(t) = \frac{v(t)}{R}$

No.

$\leftarrow \left(P = \frac{V_m I_m}{2} \right) \Rightarrow P = \frac{V_m^2}{2R}$

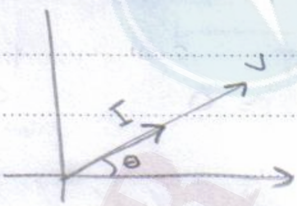
OR

$P = \frac{I_m^2 R}{2}$

$$\boxed{\Rightarrow P = \frac{I_m^2 R}{2} = \frac{I_m V_m}{2} = \frac{V_m^2}{2R}} \quad \#$$

also P (average power) we called it :

- Real power / active power / usefull power



in phase → consuming power

**ex Let $Z = Z_L = j X_L$

$v(t) = V_m \cos(\omega t + \theta)$

$I(t) = I_m \cos(\omega t + \phi) = I_m \cos(\omega t + \underbrace{\theta + 90°}_{\phi})$

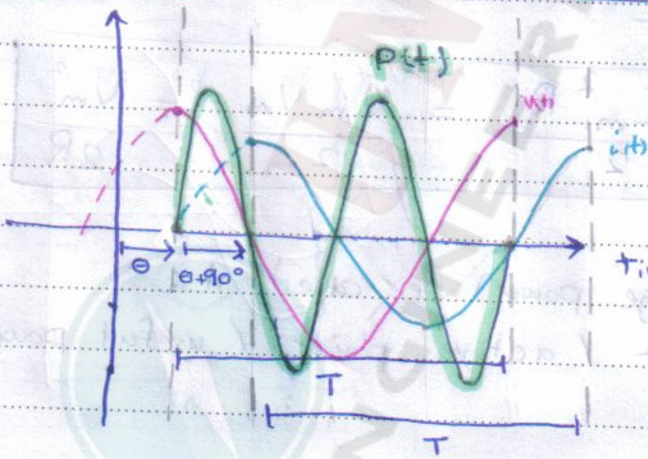
→ current lags the voltage ←

$P(t) = \frac{V_m I_m}{2} \left[\cos(\theta - \theta - 90) + \cos(2\omega t + \theta + \phi) \right] \rightsquigarrow$

No.

$\leftarrow P(t) = \frac{V_m I_m}{2}\left[\cos(90) + \cos(2\omega t + \underbrace{\theta + \phi}_{\beta})\right]$

$$P(t) = \frac{V_m I_m}{2} \cos(2\omega t + \beta)$$



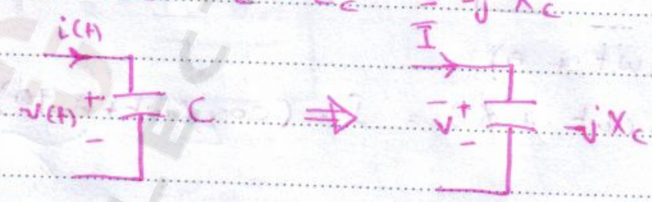
1 cycle of v(t)
OR
1 cycle of i(t)
=
2 cycles of p(t)

$P_{avg} = 0 \Rightarrow \frac{1}{T}\int v(t) \cdot i(t) = 0$

$P_{Peak} = \frac{V_m I_m}{2} \sin 90$ → this is the phase shift (sin 90 = 1)

We called it : Reactive power ($P_{avg} = 0$)

** ex. Let $z = z_c = -j X_c$ (inductor المكثف)



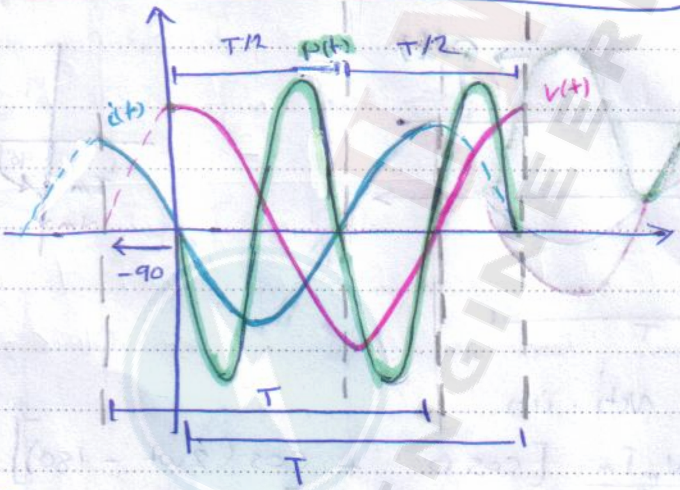
→ I leads V ←

$p(t) = V_m I_m \cos(\omega t) \cdot \cos(\omega t + 90)$

→

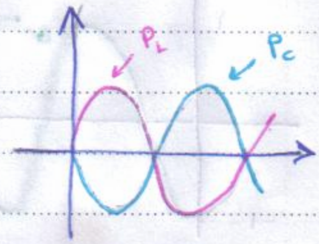
$$\leftarrow \quad P(t) = \frac{V_m I_m}{2}\left[\cos 90 + \cos(2\omega t + 180)\right]$$

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



$$P_{avg} = 0 \qquad P_{Peak} = \frac{V_m I_m}{2}$$

open cct   short cct



$$X_L = X_c$$

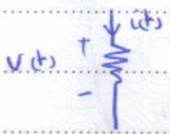
$$\omega L = \frac{1}{\omega C}$$

Resonance cct.

24-9-2014
Wednesday

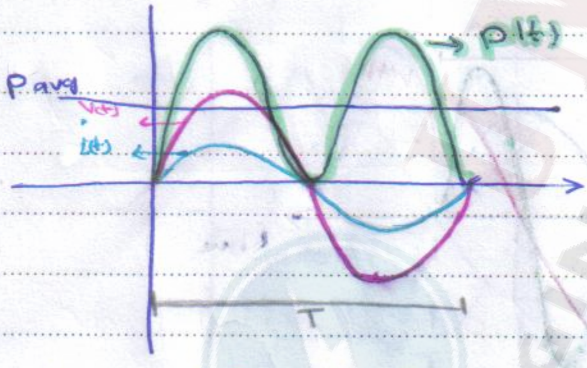
No. Lecture 4

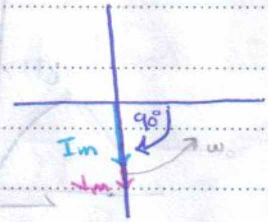
- Pure Resistive.



$v(t) = V_m \sin(\omega t) \longrightarrow \bar{V} = V_m \angle -90^\circ \text{ V}$ (with $V_m \cos(\omega t - 90)$ noted above the arrow)

$i(t) = I_m \sin(\omega t) \longrightarrow I = I_m \angle -90^\circ \text{ A}$

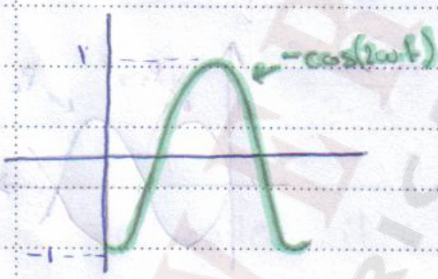




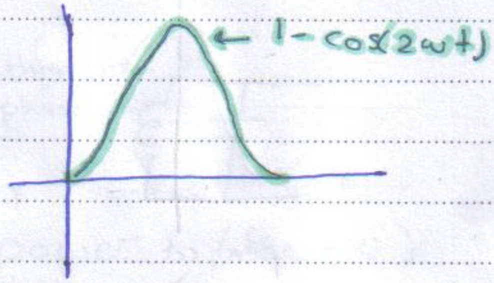
so $p(t) = v(t) \cdot i(t)$

$= \frac{V_m I_m}{2} [\cos 0 + \cos(2\omega t - 180)]$

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



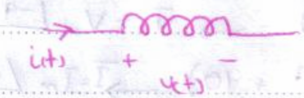
shift



$P = \frac{1}{T} \int_0^T p(t)\, dt = \frac{V_m I_m}{2}$

$P_{avg} = \frac{V_m I_m}{2} = \frac{I_m^2 R}{2} = \frac{V_m^2}{2R}$

→ Pure inductive -



$v(t) = V_m \sin(\omega t) \longrightarrow \bar{V} = V_m \angle -90$

$i(t) = I_m \sin(\omega t - 90) \longrightarrow \bar{I} = I_m \angle -180$

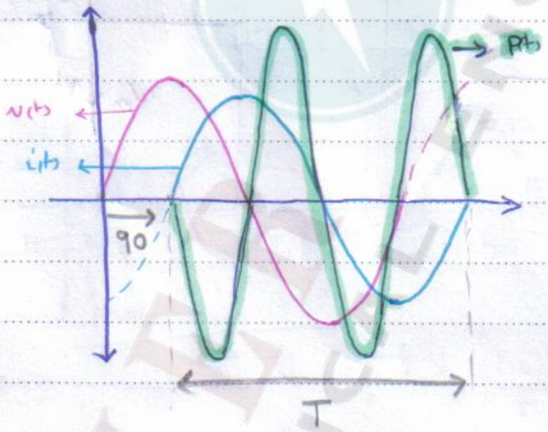
$\rightsquigarrow -I_m \cos(\omega t)$

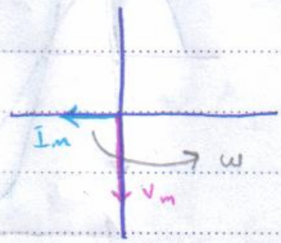
$p(t) = v(t)\, i(t)$

$= \dfrac{V_m I_m}{2} \left[\cos(\omega t - 90)\right]$

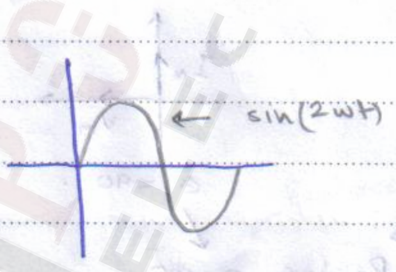
$= \dfrac{-V_m I_m}{2} \left[\sin(2\omega t)\right]$

$P_{avg} = 0 \longleftarrow$ does not consume power

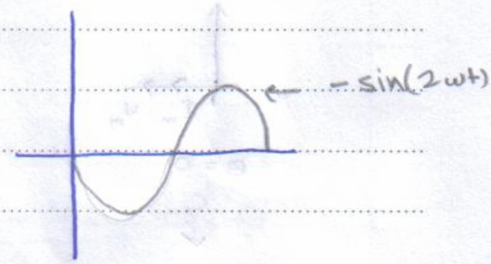




$P_{max} = \dfrac{V_m I_m}{2}$

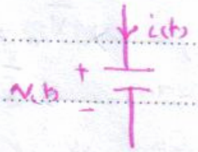


x −1 ⇝



No.

→ Pure capacitive



$v(t) = V_m \sin(\omega t) \longrightarrow \bar{V} = V_m \angle -90$

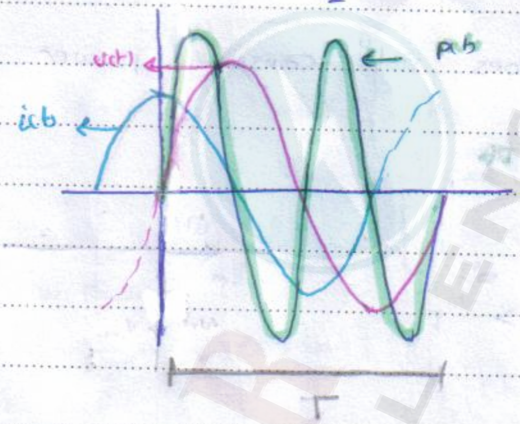
$i(t) = I_m \sin(\omega t + 90) \longrightarrow \bar{I} = I_m \angle 0$

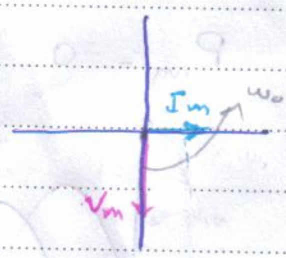
$\downarrow$

$I_m \cos(\omega t)$

$$P(t) = \frac{V_m I_m}{2} \left[\cos(90) + \cos(2\omega t - 90) \right]$$

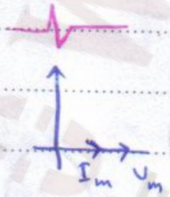
$$= \frac{V_m I_m}{2} \left[\sin(2\omega t) \right]$$



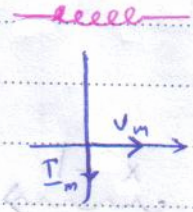


$P_{avg} = 0$

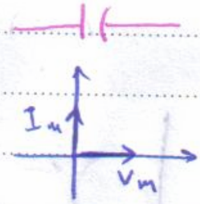
* Remember :



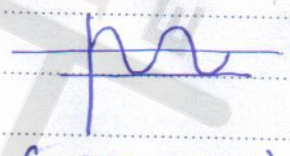
$\theta = 0$



$\theta = -90$



$\theta = 90$



(average power)

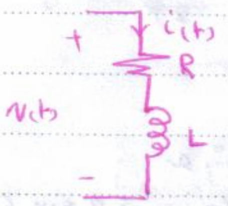
Reactive power
(Reduces the flux)

=

$\frac{V_m I_m}{2} \sin\theta$

No.

** Consider conductive load.



$v(t) = V_m \sin(\omega t) \Rightarrow V_m \cos(\omega t - 90)$

$i(t) = I_m \sin(\omega t - \theta) \Rightarrow I_m \cos(\omega t - 90 - \theta)$

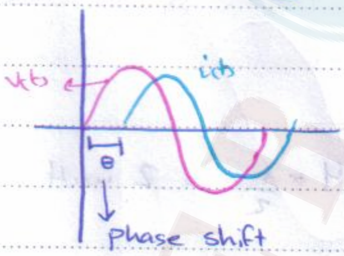
Phase shift $\Rightarrow \theta = \theta_v - \theta_i$

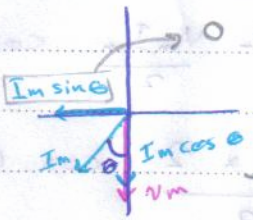
$= 90 - (-90 - \theta) = \theta$ #

$p(t) = v(t) \cdot i(t)$

$= \frac{V_m I_m}{2} \left[\cos(\theta) - \cos(2\omega t + \theta) \right]$ ← shift < 1 up/down

$P = \frac{V_m I_m}{2} \cos\theta = V_m I_m \cos(\theta_v - \theta_i)$



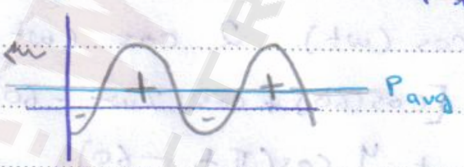


→ 0 avg power / gives me P_{max} Reactive

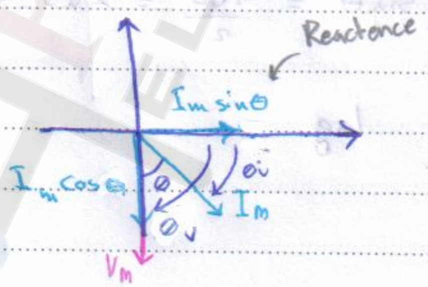
→ in phase (gives me P_{avg})

$\Rightarrow \cos\theta = \cos(\theta_v - \theta_i) \equiv$ we called it Power Factor

shifted by <1



** for capacitive



$P_R = \frac{I_m V_m}{2} \cos\theta$

$\varnothing_L = \frac{V_m I_m}{2} \sin\theta$

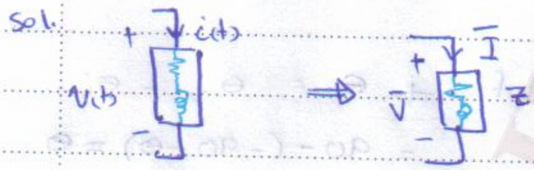
*ex. (11.2)

$v = 4\cos\left(\frac{\pi}{6}t\right)$ V $\qquad \omega = \frac{\pi}{6} \rightarrow f = \frac{\pi/6}{2\pi} = \frac{1}{2}$ Hz

$Z = 2\angle 60^\circ$

Find P, $p(t)$

Sol.



$\rightarrow 2\angle 60^\circ\ \Omega$

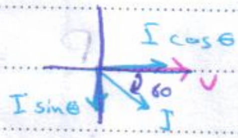
$= 2\cos 60 + j\,2\sin 60$

$= 1 + j\sqrt{3}\ \Omega$

$= R + jX_L \Rightarrow$ Inductor & Resistor

$$\bar{I} = \frac{\bar{V}}{Z} = \frac{4\angle 0}{2\angle 60} = 2\angle -60\ \text{A}$$

$$\theta = \theta_v - \theta_i = 0 + 60 = 60$$



$$\rightarrow P_{Resistor} = \frac{V_m I_m}{2}\cos\theta$$

$$P_R = \frac{4 \times 2}{2}\cos 60 = 4 \times \frac{1}{2} = 2 \text{ watt}$$

$$\text{OR} \quad P_R = \frac{I_m^2 R}{2} = \frac{(2)^2}{2} \times 1 = 2 \text{ watt}$$

$$\rightarrow p(t) = v(t) \cdot i(t) = 4\cos(\omega t) \cdot 2\cos(\omega t - 60)$$

$$= \frac{8}{2}\left[\cos(60) + \cos(2\omega t - 60)\right]$$

$$= 2 + 4\cos\left(\frac{\pi}{3}t - 60\right)$$

$$\rightarrow Q_L = \frac{V_m I_m}{2}\sin\theta = \frac{4 \times 2}{2}\sin\theta = \frac{4\sqrt{3}}{2} = 2\sqrt{3}\ \text{VAR}$$

$$\rightarrow PF = \cos\theta = \cos 60 = \frac{1}{2}\ \text{lag}$$

No. Lecture 5

note that.

① $-90 \leq \theta \leq 90$ → in phase shift

② in pf → "Lag" which means the load is inductive

"Lead" " " " " " capacitive

i □ v

Circuits II Notebook
Dr. Iyad Abulfailat

By . Isra' Jamil

بأفكارنا_نُبدع

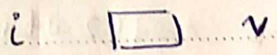
3 & 4 Weeks

note that.

① $-90 \leq \theta \leq 90$ → in phase shift

② in pf → "Lag" which means the load is inductive

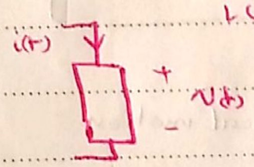
"Lead" " " " " " capacitive

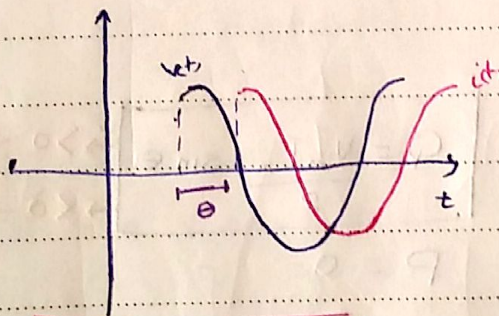


- Complex power
- Real power
- Reactive power
- power factor
- power triangle
- Examples

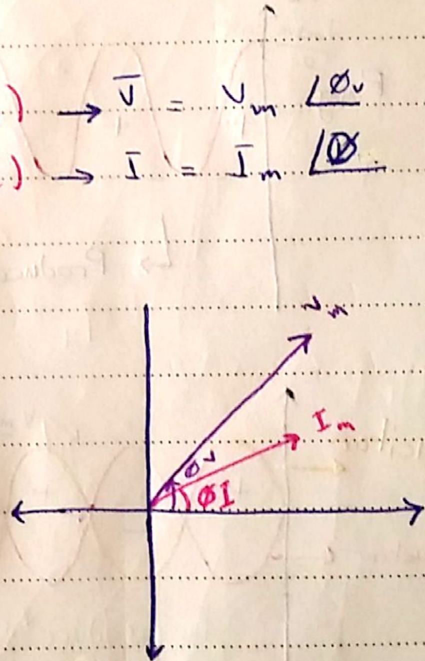
** Let $v(t) = V_m \cos(\omega t + \phi_v) \rightarrow \bar{V} = V_m \angle \phi_v$

$i(t) = I_m \cos(\omega t + \phi_i) \rightarrow \bar{I} = I_m \angle \phi$

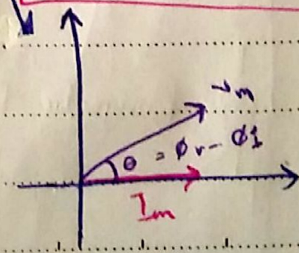




time domain



after rotation phasor domain



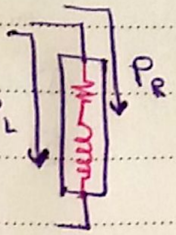
$v(t) = V_m \cos(\omega t + \phi)$

$i(t) = I_m \cos(\omega t)$

$\theta = \theta_v - \theta_i$

Inductor ↑ +ve angle

No. ....



$$p(t) = V_m \cos(\omega t + \theta) \cdot I_m \cos(\omega t)$$

$$= \frac{V_m I_m}{2}\left[\cos(\theta) + \cos(2\omega t + \theta)\right]$$

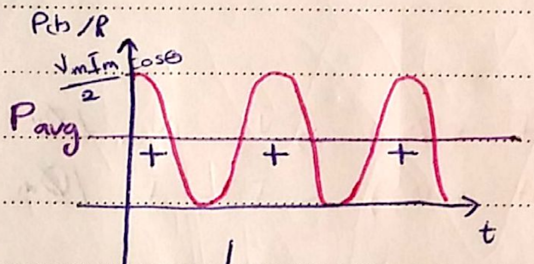
$$= \frac{V_m I_m}{2}\cos(\theta) + \frac{V_m I_m}{2}\cos(2\omega t + \theta)$$

(first term) → average power

$$P = \frac{1}{T}\int_0^T p(t)\,dt = \frac{V_m I_m}{2}\cos\theta \quad \#$$

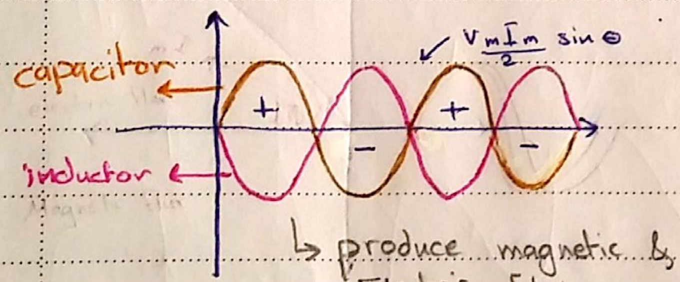
$$p(t) = \frac{V_m I_m}{2}\cos\theta + \frac{V_m I_m}{2}\cos(2\omega t) - \frac{V_m I_m}{2}\sin\theta\,\sin(2\omega t)$$

(middle terms) → P(t) from R; (last term) → P(t) from L



$$P = \frac{V_m I_m}{2}\cos\theta$$

↳ Produce → heat, light, mechanical motion



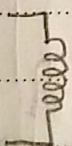
↳ produce magnetic & Electric Flux

$$Q = \frac{V_m I_m}{2}\sin\theta$$

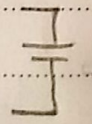
> 0 → inductor

< 0 → capacitor

$P = 0$



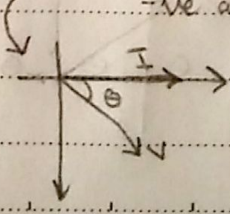
→ magnetic field



→ electric field

capacitive load

−ve angle → −ve Q



Scanned by CamScanner

No.

$$P = \frac{V_m I_m}{2} \cos\theta \quad \text{(watt)}$$ → Active / Real / Average / usefull

$$Q = \frac{V_m I_m}{2} \sin\theta \quad \text{(VAR)}$$ → Reactive

↳ (Volt Ampier reactive)

* $V_{eff} = V_{rms} = \sqrt{\frac{1}{T} \int_0^T v^2(t)\, dt}$

For pure sinosoidal,

$V_{rms} = \frac{V_m}{\sqrt{2}}$ & $I_{rms} = \frac{I_m}{\sqrt{2}}$

so,

$P = V_{rms} I_{rms} \cos\theta$ (watt)

$Q = V_{rms} I_{rms} \sin\theta$ (VAR)

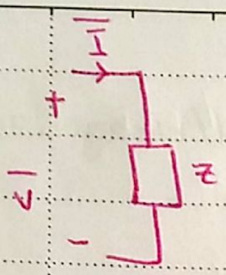
* $\cos\theta \equiv$ Power factor

$PF = \cos\theta = \frac{P}{V_{rms} I_{rms}}$

$-90 \leq \theta \leq 90$

so $0 \leq \cos\theta \leq 1$

The defult is not the rms values !!



$$Z = \frac{\bar{V}}{\bar{I}} = \frac{V\angle\theta}{I\angle 0}$$ (according to the Previous example)

$$\Rightarrow Z = \frac{|V|}{|I|}\angle\theta = |Z|\angle\theta$$

** in polar form it will be:

$$Z = \underbrace{Z\cos\theta}_{\text{Real}} \pm \underbrace{jZ\sin\theta}_{\text{img}}$$

$$\downarrow \qquad \downarrow \qquad \downarrow$$

$$Z = R \pm jX$$

- For inductive load:

$\theta = \theta_v - \theta_i > 0$

$\Rightarrow X > 0$

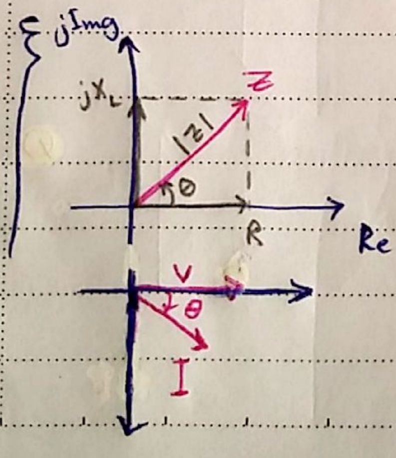
- for capacitive load:

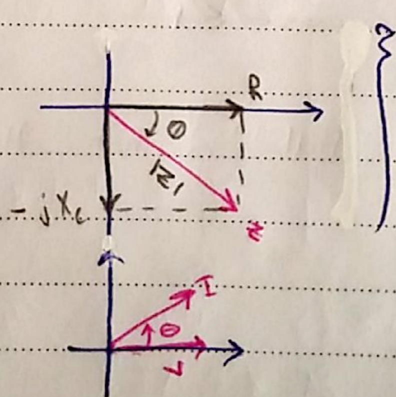
$\theta = \theta_v - \theta_i < 0$

$\Rightarrow X < 0$

$Z \rightarrow R + jX_L$ $(X_L = \omega L)$

$Z \rightarrow R - jX_C$ $(X_C = \frac{1}{\omega C})$





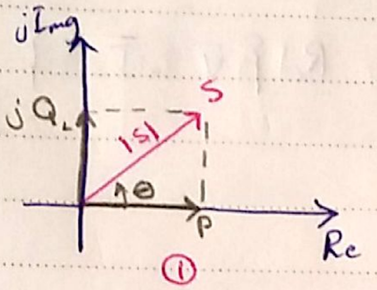
Z-triangle

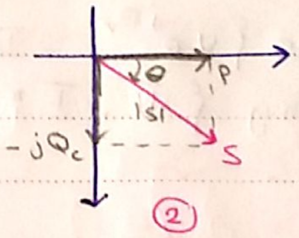
No.

** Complex power :

$S = P + jQ$ (VA) ↳ Volt Ampier

$P \rightarrow P_R$, $Q \rightarrow +Q_L$, $-Q_c$





$|S| = \sqrt{(P)^2 + Q^2}$

$\theta = \tan^{-1}\left(\frac{Q}{P}\right)$

① & ② ⇝ we call them (Power triangle)

لما السؤال يعطي PF (cosθ) لازم ← Leading OR lagging يحددلي

if P & PF is given

① → $P = S\cos\theta$

$S = \frac{P}{\cos\theta}$

$\theta = \cos^{-1}(PF)$

② → $Q = S\sin\theta$

also $S = |S| \angle\theta$ (VA)

$|S| \equiv$ Apperent power $= |V_{rms}||I_{rms}|$ (VA)

** $S = \bar{V} \cdot \bar{I}^*$

$S = |V_{rms}||I_{rms}| \angle\theta$

$S = V_{rms} I_{rms} \cos\theta + j V_{rms} I_{rms} \sin\theta$ ⇝

$S = P + jQ$

Scanned by CamScanner

No.

* note that

$$P = Re\{S\} = V_{rms} I_{rms} \cos\theta$$

$$Q = Img\{S\} = V_{rms} I_{rms} \sin\theta$$

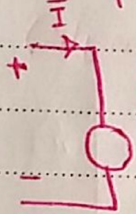
also $P = Re\{V e^{j\theta_v} \cdot I e^{-j\theta_i}\} = Re\{\bar{V} \cdot \bar{I}^*\}$

$Q = Img\{\bar{V} \cdot \bar{I}^*\}$

$$\bar{I} = I \angle \theta$$

$$I^* = I \angle -\theta$$

→ example 11.9 -Power factor correction- -Power factor improvment-

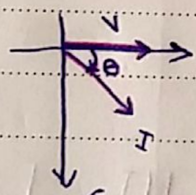


; calculate the current drawn by the motor.

sol. $pf = 0.8 = \cos\theta$

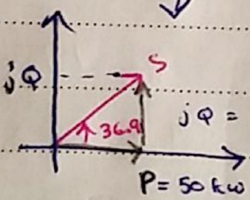
$\Rightarrow \theta = \cos^{-1}(0.8) = 36.9°$

دايماً باخد ال V refference



$\rightsquigarrow \bar{V} = 230 \angle 0$

$I = |I| \angle -\theta$



$\rightsquigarrow |S| = \frac{P}{\cos\theta} = \frac{50k}{0.8} = 62.5 \text{ kVA}$

$Q = S \sin\theta = 62.5k \times \sin(36.9)$ → 0.6

$= \boxed{37.5 \text{ kVAR}}$

⇝

No.

$\leftarrow \quad S = P + jQ = \bar{V}_{rms} \cdot \bar{I}_{rms}^{*}$

$62.5 \angle 36.9 = 230 \angle 0 \; . \; I \angle \theta$

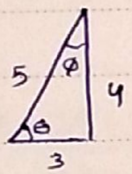
$\bar{I} = \dfrac{S^*}{\bar{V}} = \dfrac{62.5 \angle -36.9}{230} = 271.7 \angle -36.9^\circ \text{ A}$

OR $|\bar{I}| = \dfrac{|S|}{|V|} = \dfrac{62.5}{230} = 271.7$ A (as a magnetude)

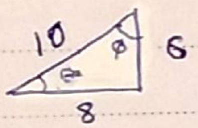
→ inductive so directly $\theta_i = -36.9^\circ$

$\Rightarrow \boxed{\bar{I} = 271.7 \angle -36.9}$ #

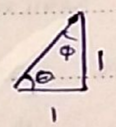
* Be familiar with these triangles.

① 

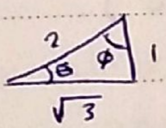
$\theta = 53.1$
$\phi = 36.9$

OR 

$\theta = 36.9$
$\phi = 53.1$

② 

$\theta = \phi = 45°$

③ 

$\theta = 30$
$\phi = 60$

OR to find Q & |S| " for the previous example

* $Q = P_{avg} \times \tan\theta = 50k \times \tan(36.9)$

$= 37.5$ kVAR

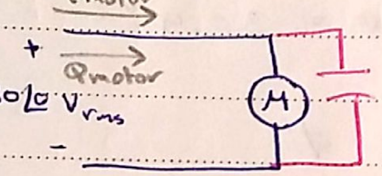
* $|S| = \dfrac{P_{motor}}{PF_{motor}} = \sqrt{(P_{motor})^2 + Q_{motor}^2}$

$= \dfrac{50k}{0.8} = 62.5$ kVA

* Note → if we increase the PF, the angle θ will decrease, so (jQ) Reactive power will decrease too.

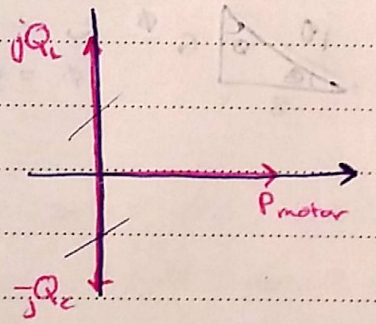
** note : we can improve P.f by:

- we can add capacitor.



$$X_c = \frac{1}{\omega C} = \frac{1}{2\pi f C}$$ where $\omega = 2\pi f$ & $F = 50 H_z$

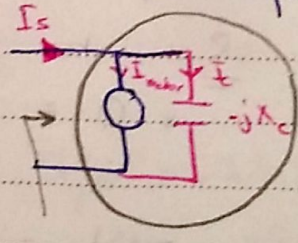
& $\omega = 314$ rad



$jQ_L = jQ_c$

⇝ they will cancel each other so the reactive power will be zero. (there will be just average power).

⇝ back to the example, we need to improve the pf to 0.95



$PF_{new} = 0.95$ lagging.

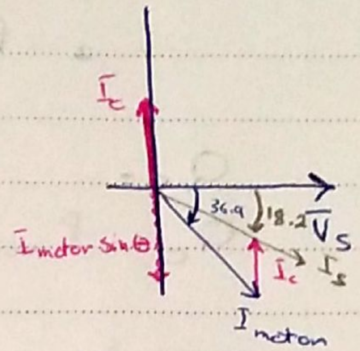
$\theta_{new} = \cos^{-1}(0.95) = 18.2°$

PF = 0.95 lagging

$|I_c| = \frac{|V_c|}{|X_c|}$ $\quad Q_c = \frac{V_{c\,rms}^2}{X_c} = V_{c\,rms}^2 \times \omega C$

No.

$\bar{I}_c = \frac{\bar{V}_s}{-jX_c} = \frac{+j\bar{V}_s}{X_L} = \frac{\bar{V}_s}{X_c} \angle 90°$



$P_{motor} = |V_s||I_{motor}| \cos\theta = 50\,kV$

$Q_{motor} = |V_s||I_{motor}| \sin\theta =$

$I_{motor} = \frac{P_{motor}}{V_s \cos\theta} = \frac{50 \times 10^3}{230 \times 0.8} = 271.7\ A$

↳ $\bar{I}_{motor} = 271.7 \angle -36.9°\ A$

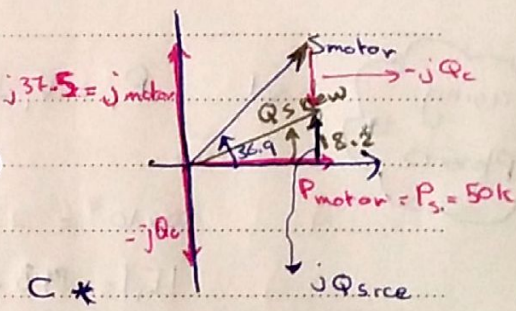
$P_{source} = |V_s||I_s| \cos\theta$

$50\,kW = 230\,|I_s|\,0.95$

adding the capacitor will not effect the P

$|I_s| = \frac{50 \times 10^3}{230 \times 0.95} - 228.8\,A$

using power triangle



$Q_{source} = |V_s||I_s| \sin\theta$

$= 230 \times 228.8 \times \sin(18.2)$

$= 16.4k\ VAR$

$\tan\theta = \frac{Q}{P}$

$\rightarrow Q = P \tan\theta$

* $|S_{motor}|$ is = S_{source} before adding the C *

$S_{source} = S_c + S_{motor}$

$= -jQ_c + (P_{motor} + jQ_{motor})$

→

Scanned by CamScanner

No. ....

$\leftarrow = P_{motor} + j[Q_{motor} - Q_c]$

$= P_{motor} + jQ_{sorce}.$

$Q_c = P_{motor}[\tan\theta_{old} - \tan\theta_{new}]$

$\omega C V_{c_{rms}}^2 = 50 \times 10^3 [\tan(36.9°) - \tan(18.2)]$

$(314) * C(230)^2 = 21.1 \times 10^3$

where $\omega = 314$

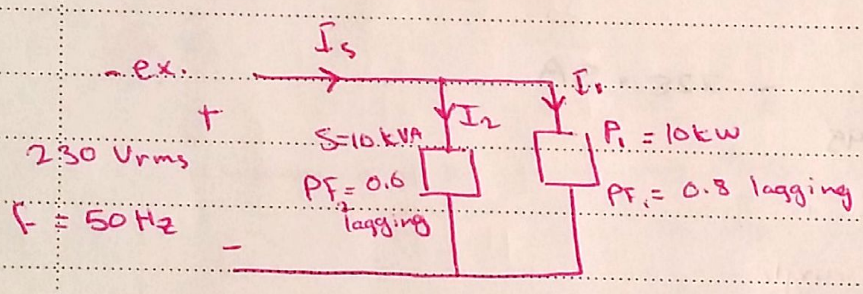
& $Q_c = \frac{V_{c_{rms}}^2}{X_c}$

$\Rightarrow C = \frac{21.2 \times 10^3}{314(230)}$

$\Rightarrow C = 1.3\, mF$

$\rightsquigarrow Q_c = V_{c_{rms}}^2 * \omega C$

ex.



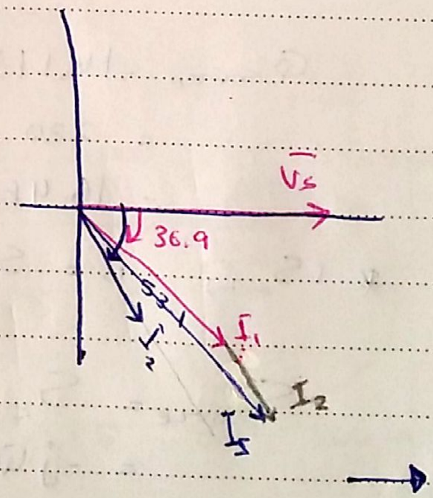
using phasors ⇒

sol $P_1 = V_1 I_1 \cos\theta_1$ (θ_1: $V_s \wedge I_1$)

$10 \times 10^3 = 230 \times |I_1|\, 0.8$

$|I_1| = 54.3$ A

$\rightarrow I_1 = 54.3 \angle -36.9$



No.

$\rightarrow S_2 = |V_s| |I_2|$

$10 \times 10^3 = 230 |I_2|$

$\Rightarrow |I_2| = 43.4 A$

$\rightarrow I_2 = 43.4 \angle -53.1^\circ A$

$\bar{I}_s = \bar{I}_1 + \bar{I}_2$

$= 54.3 \angle -36.9 + 43.4 \angle -53.1$

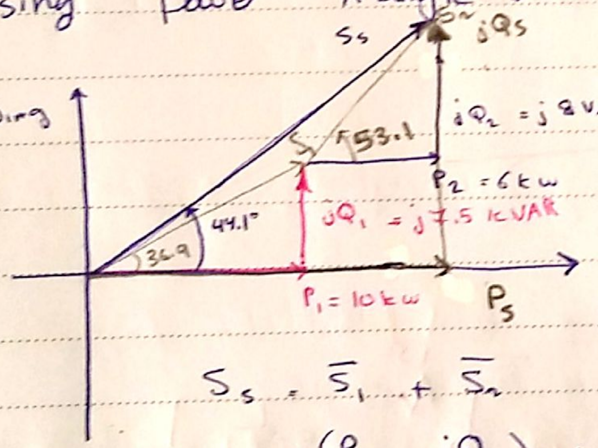
$= 96.7 \angle -44.1$

$\bar{S}_2 = \bar{V}_s * \bar{I}_2^*$

$= P_2 + jQ_2$

$= |S|_2 \angle \theta_2$

(II) using power triangle :



$S_s = \bar{S}_1 + \bar{S}_2$

$= (P_1 + jQ_1) + (P_2 + jQ_2)$

$= (10 + j7.5) + (6 + j8)$

$= 16 + j15.5$ kVA

$= 22.3 \angle 44.1$ kVA

$\rightarrow P_s = 16$ kw & $Q_s = 15.5$ kVAR

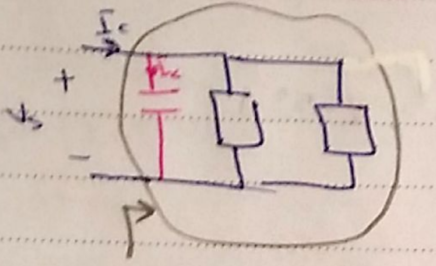
Scanned by CamScanner

No.

$PF_{new} = \cos(44.1)$

$= 0.72$ lagging.

→ to improve PF to a unity power factor we will add the capacitor.



$Q_c = P_{rat}\left[\tan\theta_{old} - \tan\theta_{new}\right]$

$= 16k\left[\tan 44.1 - \tan 0°\right]$

$= 15.5$ k VAR

$\omega C V_{c\,rms}^2 = Q_c$

$(314)(C)(230)^2 = 15.5 \times 10^3$

$C = 9.3 \times 10^{-4}$

$= 0.93$ mF

$= 930\ \mu F$

example : (Practice 11.9)

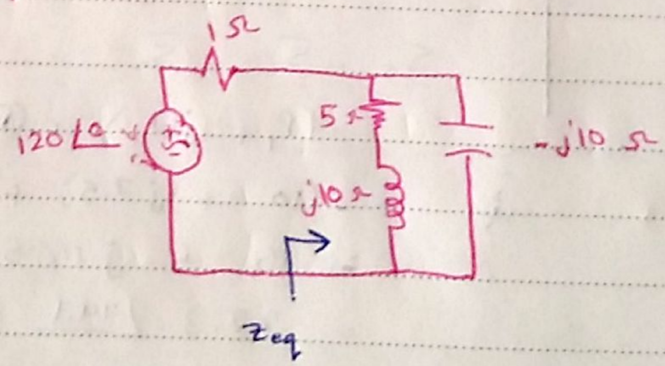
Find :

a) $\bar{S}_{R=1\Omega}$

b) $\bar{S}_{C=-j10\Omega}$

c) $\bar{S}_{5+j10\Omega}$

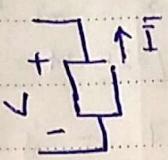
d $\bar{S}_{source}$



⟿

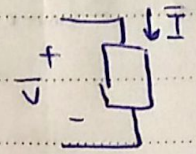
sol.

NOTE :-



$\bar{S} = V . I^*$

$P > 0$, $Q > 0$] generated power



$\bar{S} = \bar{V} . \bar{I}^*$

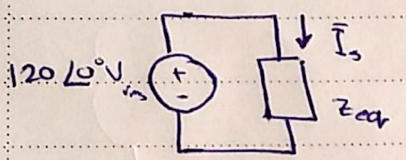
$= P + jQ$

absorbed ← { $P > 0$, $Q > 0$ }

$P > 0$ → absorbed

$Q < 0$ → generated

** we will find the current.



$Z_{eq} = -j10 \parallel (5 + j10) + 1 \ \Omega$

$= \dfrac{10 \angle -90 * 11.1 \angle 63}{5 + j10 - j10} + 1 \ \Omega$

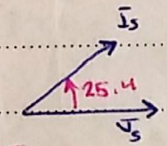
$= \dfrac{111 \angle -26.6}{5} + 1 \ \Omega$

$= 22.2 \angle -26.6 + 1 \ \Omega$

$= 20.8 - j9.9 \ \Omega$

$= 23.09 \angle -25.4° \ \Omega$

$\rightsquigarrow \bar{I}_s = \dfrac{V_s}{Z_{eq}} = \dfrac{120 \angle 0}{23.09 \angle -25.4} = \boxed{5.2 \angle +25.4 \ A_{rms}}$



I_s lead V_s → Capacitive load.

$|I_s| = 5.2 \ A$

$\bar{S}_{source} = \bar{V}_s * I_s^*$

$\rightsquigarrow$

No.

$\bar{S}_{source} = 120 \angle 0° \times 5.2 \angle -25.4°$

$= 624 \angle -25.4$ VA

$= 563.7 - j\,267.7$ VA

$\Rightarrow P = 563.7$ watt (generated power)

$\Rightarrow Q = -267.7$ VAR (capacitive)

& $P_{absorbed} = -563.7$ watt

$Q_{absorbed} = 267.7$ VAR] according to the convention!

Note : angle of the power is − (the angle of the current

$\rightarrow \bar{S} = \bar{V} \times \bar{I}^*$

$= \dfrac{\bar{V} \times \bar{V}^*}{Z^*} = \dfrac{|V|^2}{Z^*}$

$P_{1\Omega} = |I_{rms}|^2 R$

$= (5.2)^2 (1) = 27.04$ W

** By $\xrightarrow[\text{divider}]{\text{current}}$ $\bar{I}_L = \dfrac{\bar{I}_s \times (-j10)}{5+j10 - j10}$

$= \dfrac{5.2 \angle 25.4 \times 10 \angle -90}{5}$

$\Rightarrow I_L = 10.4 \angle -64.6°$ A_{rms}

$\Rightarrow I_C = I_s - I_L$

$= (4.7 + j2.2) - (4.5 - j9.3)$

$= 0.2 + j11.5$ A_{rms}

$= 11.5 \angle 89°$ A_{rms}

$\bar{I} \cdot I^* = |I|^2$

No.

← $S_L = \bar{V}_L \cdot \bar{I}_L^*$

$= I_L \cdot Z_L \cdot I_L^* = |I|^2 \cdot Z_L = (10.4)^2 (5 + j10)$

$S_L = 1209.3 \angle +63.4$ VA (polar form)

absorbed ← $S_L = 540.8 + 1081.6j$ VA (rectangular form)

$P_L = 540.8$ W

$Q_L = 1081.6$ VAR

$S_c = \bar{V}_c \cdot \bar{I}_c^*$

$= V_c \cdot Z_c \cdot I_c^*$

$= |I_c|^2 \cdot Z_c = (11.5)^2 (10 \angle -90)$

$= -j\,1322.5$ VAR → absorbed

C generates 1322.5 VAR

$\sum_{generate} S = \sum_{absorbed} S$

$P_{generated} = 563.7$ W

$P_{absorbed} = 27.04 + 540.8 = 567.8$ W

$Q_{generated} = 1322.5$ VAR

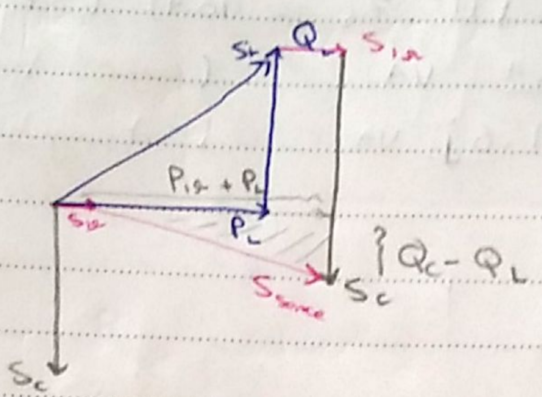
$Q_{absorbed} = 267.7 + 1081.6 = 1349.3$ VAR

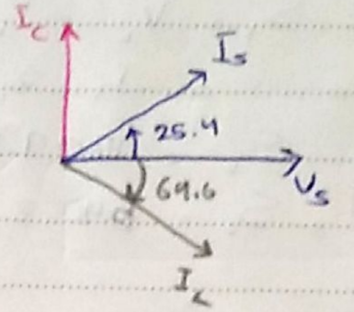
OR $\sum S = 0$

$\bar{S}_{source} + \bar{S}_L + S_c + \bar{S}_{12} = 0$

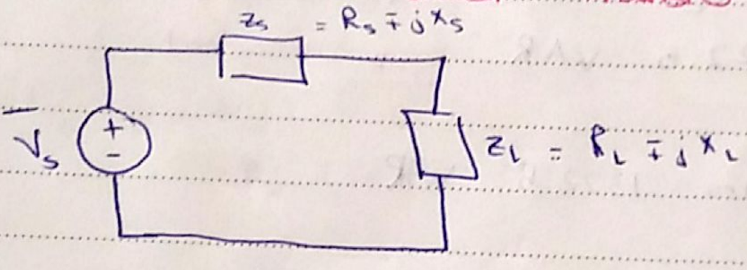
Scanned by CamScanner

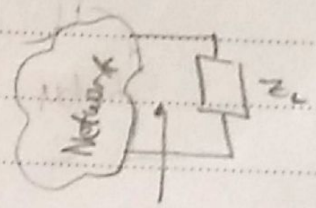
No.

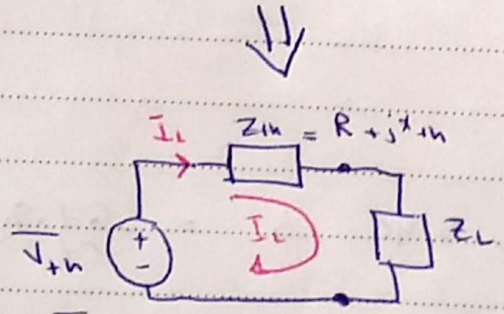




** Maximum Power transfer







** $\bar{I}_L = \dfrac{\bar{V}_{th}}{Z_{tot}} = \dfrac{\bar{V}_{th}}{(R_{th} + jX_{th}) + R_L + jX_L}$

$$\bar{I}_L = \frac{\bar{V}_{th}}{(R_{th} + R_L) + j(X_{th} + X_L)}$$

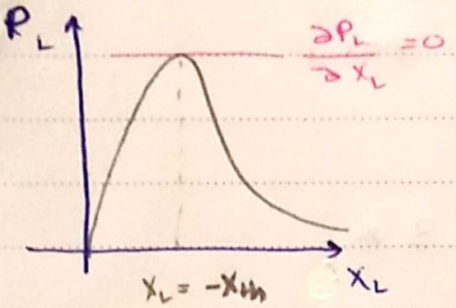
No.

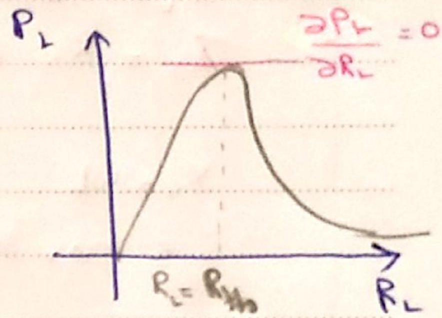
←

$$|I_L| = \frac{|V_{th}|}{\sqrt{(R_{th}+R_L)^2 + (X_{th}+X_L)^2}}$$

$$P_L = |I_L|^2 * R_L$$

$$= \frac{|V_{th}|^2 * R_L}{(R_{th}+R_L)^2 + (X_{th}+X_L)^2}$$





→ P_{max} occurs when :-

$$\bar{Z}_L = \bar{Z}_{th}^*$$

@ maximum power

$$\bar{I}_L = \frac{\bar{V}_{th}}{R_{th} + R_L} = \frac{\bar{V}_{th}}{2 R_{th}}$$

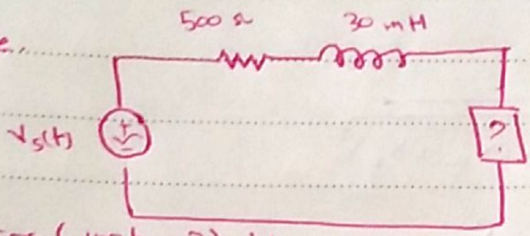
$$P_{max} = |I_L|^2 \cdot R_L$$

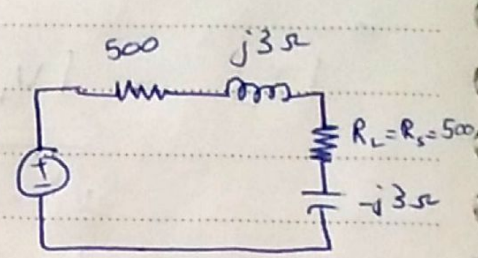
$$= \frac{|V_{th}|^2}{4 R_{th}^2} R_{th}$$

$$\Rightarrow \boxed{P_{max} = \frac{V_{th\,rms}^2}{4 R_{th}}}$$

No.

- example.



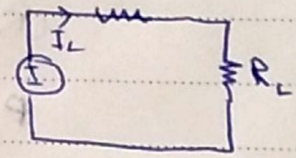


$v_s(t) = 3\cos(100t - 3)$ V

sol. For P_{max} delivering

$Z_L = Z_s^*$

$Z_s = R_s + jX_s = 500 + j3$



$X_s = \omega L$

$= 100 \times 30\,H = 3\,\Omega$

$$P_{max} = \frac{|V_s|^2_{rms}}{4R_s} = \frac{}{4 \times 500} = \frac{9/2}{4 \times 500} = \frac{9}{4 \times 1000}$$

$= 2.25$ mW

$$X_c = \frac{1}{\omega c}$$

$$c = \frac{1}{\omega X_c} = \frac{1}{(100)(3)}$$

C = 3.33 mF