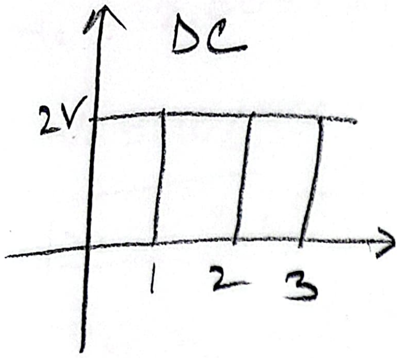
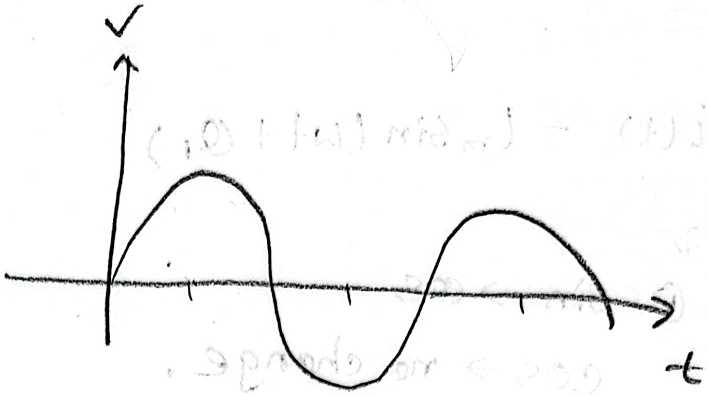
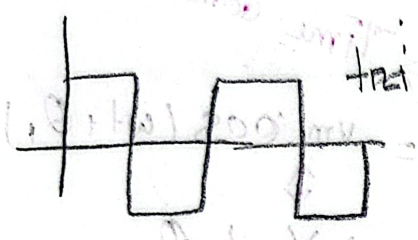
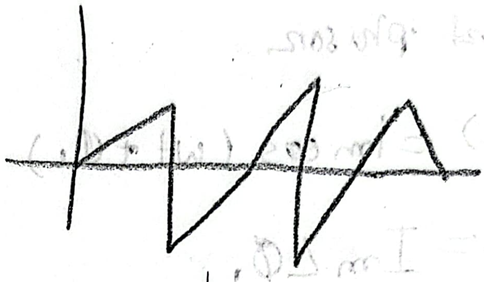
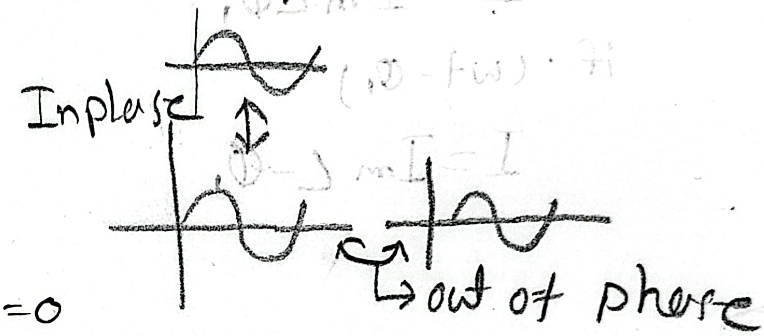
AC circuit





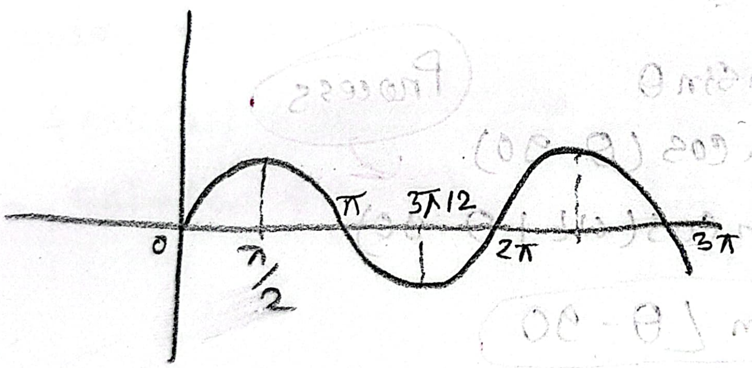






$V = V_m \sin(\omega t + \phi)$

$V = V_m \sin(\omega t + \phi)$, $\phi = 0$

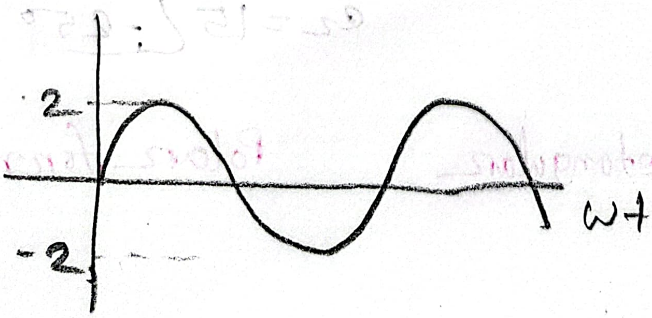


$\sin(\omega t + \phi)$ $\theta \to -\theta_1$

$\sin(\omega t - \phi)$ $\theta \to +\theta_1$

$\theta = 0 \to 0$

$V = \cancel{V_m}\ 2 \sin(\omega t + \phi)$



phasor / frequency domain

① $i(t) = I_m \sin(\omega t + \theta_1)$

step 1

① $\sin \rightarrow \cos$

$\cos \rightarrow$ no change.

Example convert phasor

$i(t) = i_m \cos(\omega t + \phi_1)$

$I = I_m \angle \phi_1$

if $(\omega t - \theta_1)$

$I = I_m \angle -\phi_1$

→ Time domain

$v_1(t) = v_m \cos(\omega t + \theta_1)$

⇕

$V_1(t) = V_m \angle \theta_1$

↳ phasor

$\boxed{\sin\theta = \cos(\theta - 90^\circ)}$

9.1

$V_m \sin(\omega t + \theta) \rightarrow V_m \sin\theta$

Process

$\Rightarrow V_m \cos(\theta - 90)$

$\Rightarrow V_m \cos(\omega t + \theta - 90)$

$\Rightarrow \boxed{V_m \angle \theta - 90}$

Complex number

$x + iy$ / $a + i\beta$

↓ real ↓ imaginary

→ complex number rectangular form

$3 + i8$

$c_1 = 20 \angle 90^\circ$

$c_2 = 15 \angle -25^\circ$

Polar form

$v_1 = 10\cos(\omega t + 70)$

$v_2 = 2\cos(\omega t + 50)$

30 .

10

$2\sin(\omega t + 50)$

$2\cos(\omega t + \theta - 90)$

$\boxed{2\angle\theta - 90'}$

$\theta - 90° =$

$v_1 = 10\angle 70°$

$\boxed{v_2 = 2\angle 50}$

$v_2 = 2\angle(\theta - 50)$

$i. \quad 5\angle -20° - 90°$

$v = v_1 + v_2$

$v = -4\angle 50 - 90$

$-5\sin(\omega t + 50)$

$5\cos($

Retangular to polar:

$i_1 = 4\cos(\omega t + 30°) \rightarrow 4\angle 30°$ — ①

$i_2 = 5\sin(\omega t - 20°) \quad 5\angle -20 - 90$

$= 5\angle -110$ — ⑪

$I = i_1 + i_2 = 4\angle 30° + 5\angle -110$

$= 3.21\angle -56.97$

Polar to rect

4.

(a) ~~4∠50~~

$$(40\angle 50^\circ + 2\angle -30^\circ)^{1/2}$$

$40\angle 50^\circ$ $40(\cos 50^\circ + j\sin 50^\circ)$

$= 25.71 + j\,30.64$

$2\angle -30^\circ$

$= 20[\cos(-30) + \sin(-30)\, j]$

$= 17.32 - j10.$

$(\cancel{43.03 + j\,20.64})^2$

$43.03 + j\,20.64$

~~lead~~ lag / Leading

5 sin

$v_1 = -10\cos(\omega t + 50°)$

$v_2 = \cancel{12}\ 12\sin(\omega t - 10°)$

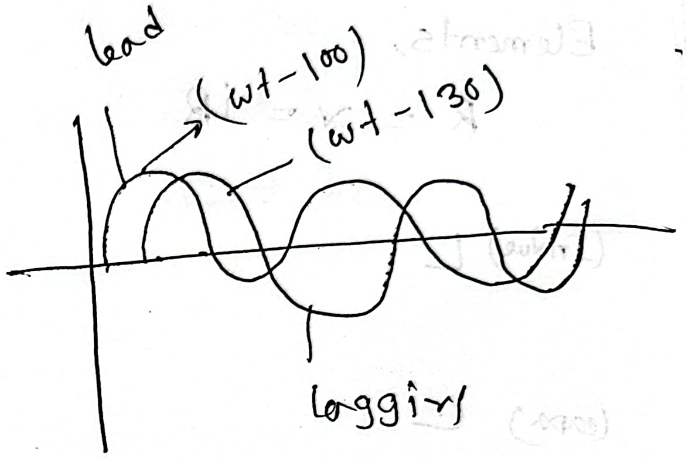
$-\cos(\omega t) = \cos(\omega t \pm 180°)$

$\phi \to + \to$ বামে

$\phi \to - \to$ ডানে

$v_1 = 10\cos(\omega t + 50 - 180°)$

$= 10\cos(\omega t - 130°)$



$v_2 = 12\cos(\omega t - 10° - 90°)$

$= 12\cos(\omega t - 100)$

here, v_2 is leading

v_1 is lagging.

$-\sin(\omega t) = \sin(\omega t \pm 180°)$

Capacitance, Inductance, Impedence

↳ Inductance

↳ Re: $V = IR$: Ω

↳ capacitance (complex) Ω

Elements,

R = $v = iR$

(Induc) L

(capa) C

Frequency / Phasor

$V = RI$

$V = IZ = I\,j\omega L$

$V = IZ = I \cdot \dfrac{1}{j\omega C}$

Exp

9.8

$v = 12\cos(60t + 45^\circ)$

$V = j\omega L I$

$I = \dfrac{V}{j\omega L}$

$j = j$

$\omega = 60$ rad/s

$V = 12\angle 45^\circ$

$L = 0.1$

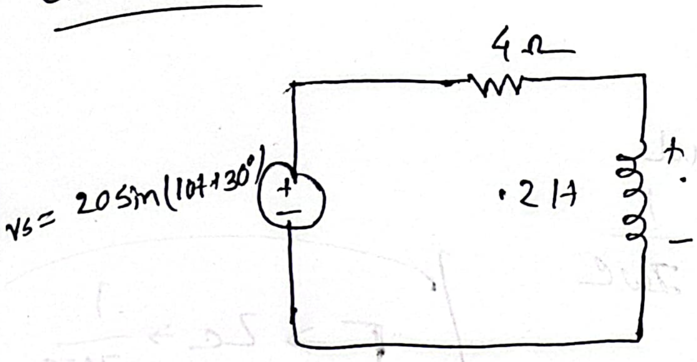
$= \dfrac{12\angle 45^\circ}{j60 \times 0.1}$

$= \dfrac{12\angle 45^\circ}{6j}$

$= 2\angle -45$

$= 2\cos(60t - 45^\circ)$

Example 9.9

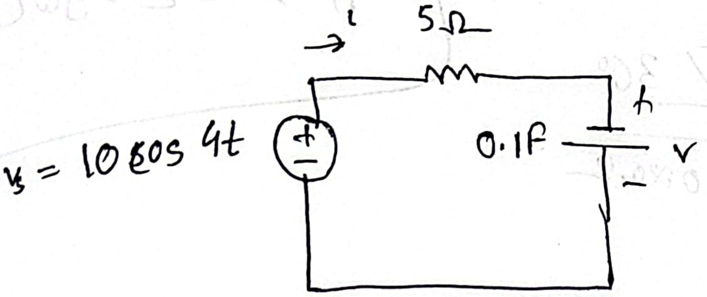


① $T_D \rightarrow P_D$

② $R - Z_R$

$C \rightarrow Z_C$

$L \rightarrow Z_L$



$V_s = 10\angle 0$

$\omega = 4$

$R = 5$

$c = 0.F$

$Z_C = \dfrac{1}{j\omega C}$

$= \dfrac{1}{j4 \times 0.1}$

$= \dfrac{1}{j.4}$

$= -j2.5$

$I = \dfrac{V}{Z_{eq}}$

$= \dfrac{10\angle 0}{5-2.5j}$

$1.789 \angle 26.566$

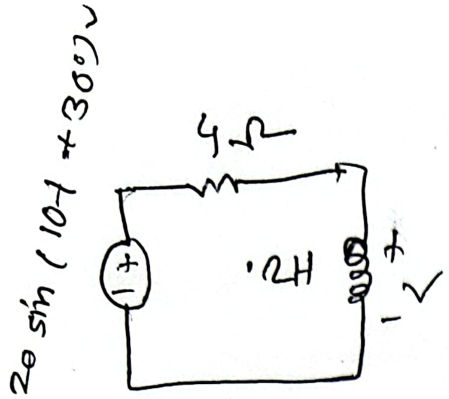
$V = I Z_C$

$= 1.789\angle 26.566 \times (-2.5j)$

$= 4.47 \angle -63.43$

$i(t) = 1.789 \cos(4t + 26.59)$

$v_C(t) = 4.47\cos(4t - 63.43°)$



$Z_R = R$

$Z_L = j\omega L$

$Z_C = \frac{1}{j\omega C}$

$F \rightarrow Z_C \rightarrow \frac{1}{j\omega C}$

$H \rightarrow Z_L \rightarrow j\omega L$

$I = \frac{V}{Z_{eq}}$

$= \frac{V}{Z_R + Z_L} = \frac{20\cancel{\phi}\angle 30^\circ}{4 + j10 \times 0.2}$

$= \cancel{\quad\quad\quad}$

$= 4.97 \angle 3.4 = 4.97 \sin(10t + 3.4^\circ)$ A

$V = IR = IZ$

$= (4.47\angle 3.4^\circ)(j10 \times 0.2)$

$= 8.94 \angle 93.4^\circ$

$= 8.94 \sin(10\cancel{t} + 93.4^\circ)$

$m \rightarrow 10^{-3}$

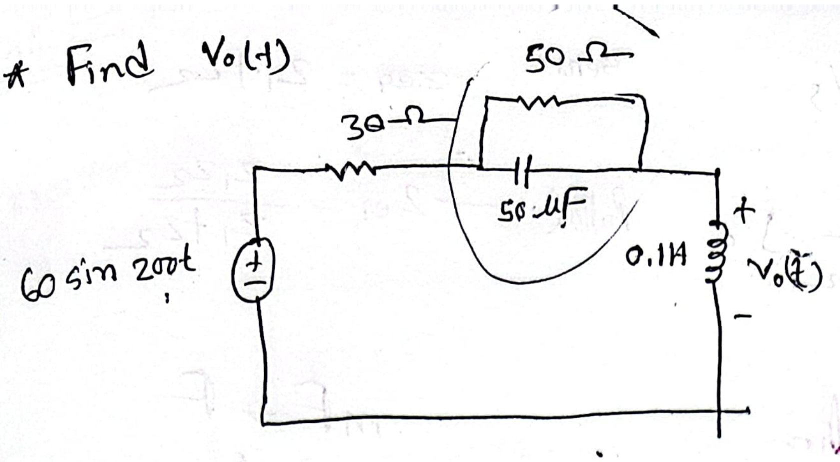
$\mu \rightarrow 10^{-6}$

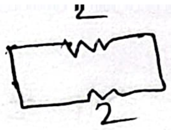
$n \rightarrow 10^{9}$

$k \rightarrow 10^{3}$

$M \rightarrow 10^{6}$

* Find $V_o(t)$





$\frac{1}{2} + \frac{1}{2}$

$\mu \to F$

$x \times 10^{-6}$

$\frac{1}{50} + \frac{1}{j200 \times 50\times10^{-6}}$

$100 \angle -89.98$

$\frac{50 \times \frac{1}{j200\times50\times10^{-6}}}{50 + j200\times50\times10^{-6}}$

① Z_{eq}

$30 + \frac{50 \times \cancel{\ldots}}{} + \cancel{\ldots}$

$\sqrt{2} I R$

$\frac{1}{j\omega C}$

VDR $\rightarrow$ $V_1 = \frac{Z_1}{Z_1+Z_2} V_s$

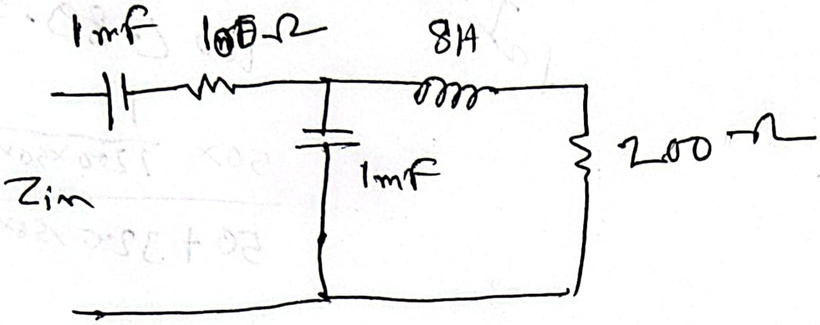
Serie $Z_{eq} = Z_1 + Z_2$

CDR $\rightarrow$ $I_1 = \frac{Z_2}{Z_1+Z_2} I_s$

Parallel $- Z_{eq} = \frac{Z_1 Z_2}{Z_1+Z_2}$

9.7 Impedance Combination

mF $\rightarrow$ F
10^{-3}



$\omega = 10$ rad/s

$R = Z_R = 100\,\Omega$

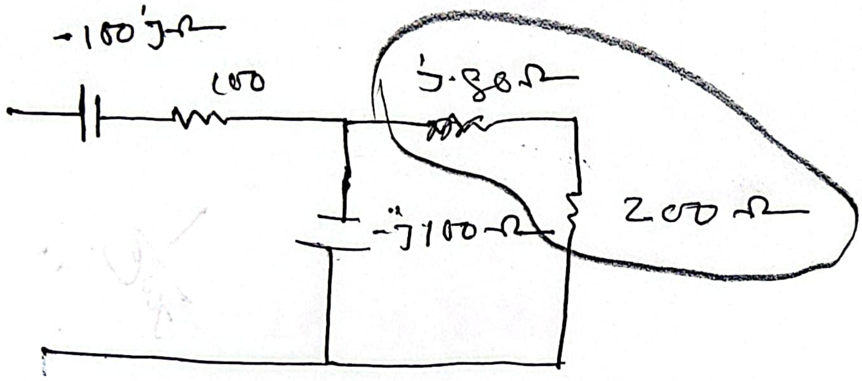
$L \rightarrow Z_L = j\omega L$

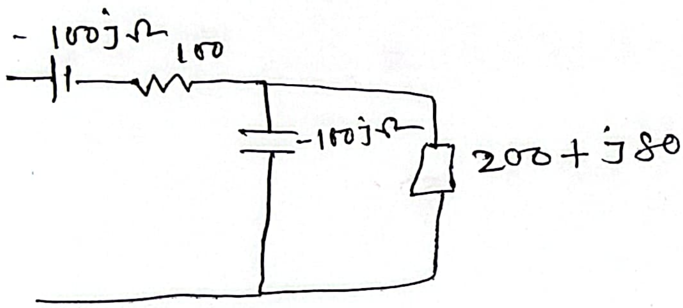
$= (10 \times 80) j$

$= j80\,\Omega$

$C \rightarrow Z_C \rightarrow \frac{1}{j\omega C}$

$= \frac{1}{j10 \times 1 \times 10^{-3}}$

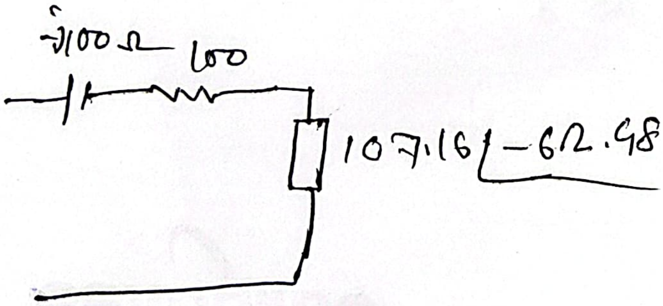




Parallel $Z = -j100\,\Omega$

$\frac{(-j100) \times (200 + j80)}{-j100\,\Omega + 200 + j80}$

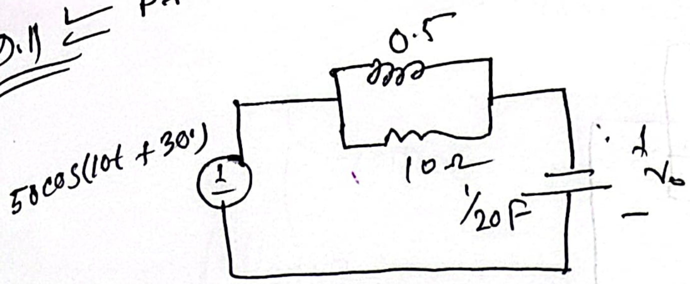
$= 107.16 \angle -62.48$

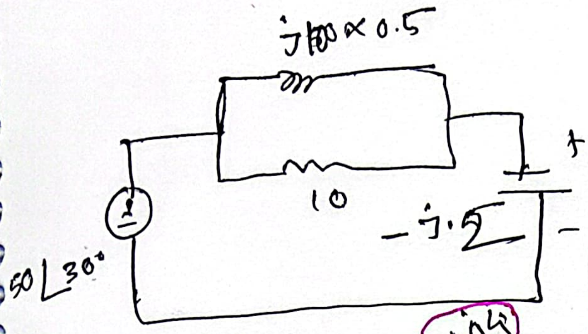


$\therefore Z_{in} = -j100\,\Omega + 100 + 107.16 \angle -62.48$

$= 245.75 \angle -52.52$

9.11 ⟸ P.P





$\frac{1}{j\times10\times\frac{1}{20}} = \frac{\cancel{20}\,2}{j\times\cancel{10}}$

$= -2j$

2+j4

$$Z_{eq} = \frac{10\times j5}{10\times j5} + (-j2) = 2+2j$$

$$I = \frac{V}{Z_{eq}} = \frac{50\angle30^\circ}{2+2j} = \frac{50\angle30^\circ}{2.82\angle45}$$

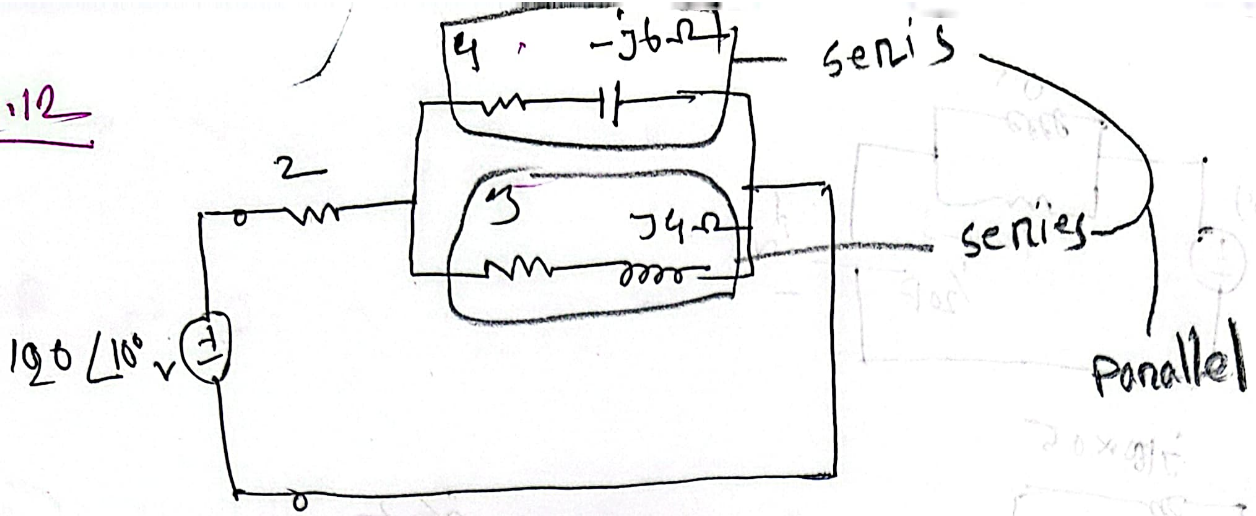
$$= 17.73\angle-15$$

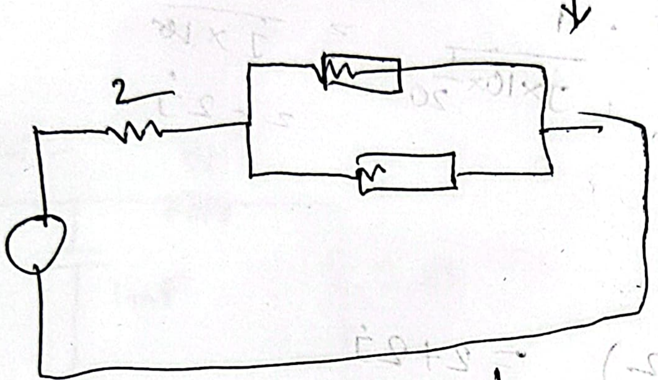
$$V = IZ_c = 17.73\angle-15 \times (-j2)$$

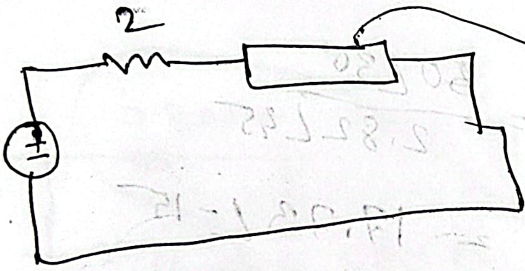
$$= 35.46\angle-105$$

$\therefore$ 35.46 cos (10t − 105°) V.

9.12

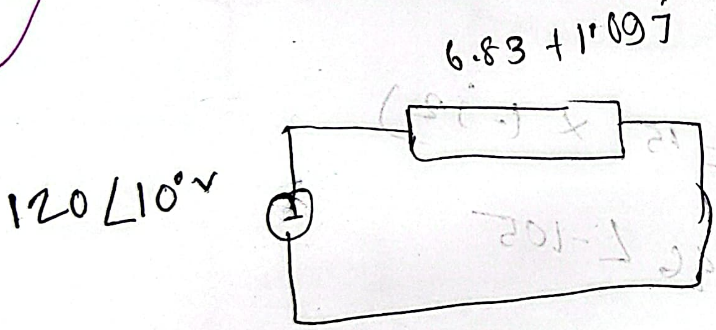






$$\frac{(4-j6)(3+j4)}{(4-j6)+(3+j4)}$$

$= 4.83 + 1.09j$



$Z_T = 4.83 + 1.09j + 2$

$= 6.83 + 1.09j$

$$\therefore I = \frac{V}{Z_T} = \frac{120\angle 10^\circ}{6.83+1.09j}$$

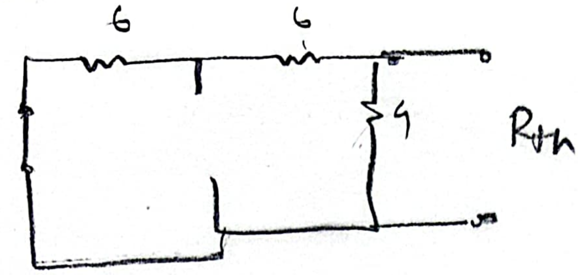
$\rightarrow r\angle\theta = 6.91\angle 9.06$

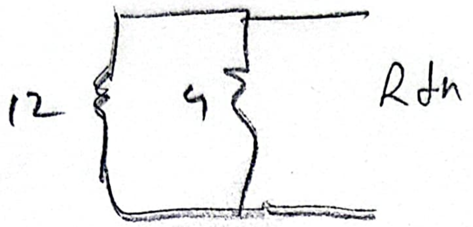
$= 17.41\angle 10$ — (11')

$= 17.36\angle 0.94$ — (1')

Exp - 9.9, 9.10, 9.11
PP - 9.9, 9.10, 9.11
39, 41, 42, 43, 46, 48, 50, 52

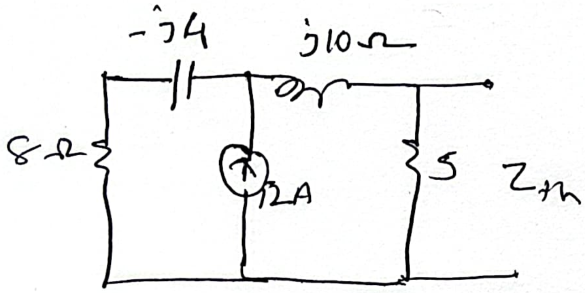
Thevenin



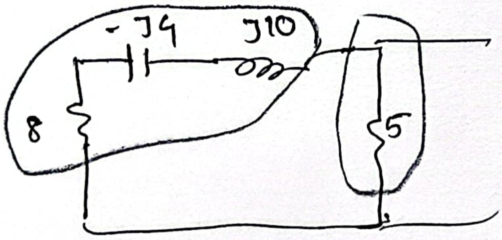


$$\frac{\cancel{12}^{3}\times \cancel{4}}{\cancel{16}_{4}} = 3\,\Omega$$

max power in 1 A eq



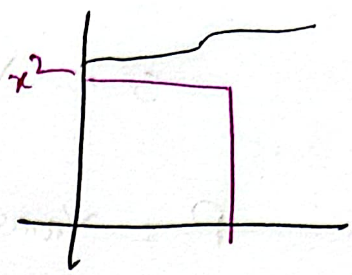
$$Z_{th} = \frac{(+8 - j4 + j10)\times 5}{5+8+j6}$$



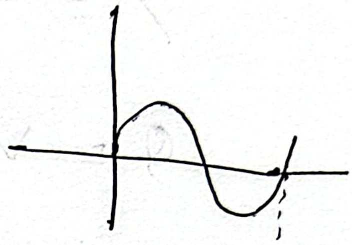
11.4 avg, x_{rms}

$$x_{avg} = \frac{1}{T}\int_0^T x(t)\,dt$$

↳ area



$$x = x_{rms} = \sqrt{\frac{1}{T}\int_0^T x^2(t)\,dt}$$



Sine-wave,

$$v_{rms} = \frac{v_m}{\sqrt{2}}$$

$$v_{avg} = \; = 0$$

$$r_1\angle\theta_1 \times r_2\angle\theta_2$$
$$r_1 r_2 \angle\theta_1+\theta_2$$
$$= x+iy$$

Power

DC: $P = VI$

AC: $P = v(t) \cdot i(t)$

- → apparent power (S)
- → real power (P)
- → reactive power (Q)

$$V = V_m \angle\theta_v$$

$$I = I_m \angle -\theta_i$$

$$P = VI = (V_m\angle\theta_v)(I_m\angle -\theta_i)$$
$$= V_m I_m \angle\theta_v - \theta_i$$
$$= V_m I_m \cos(\theta_v - \theta_i)$$
$$+ j\, V_m I_m \sin(\theta_v - \theta_i)$$

115 Apparent Power.

$S = P + jQ$ → reactive
↳ real power

$$S = V_{rms} \cdot I_{rms} \cos(\theta_v - \theta_i)$$

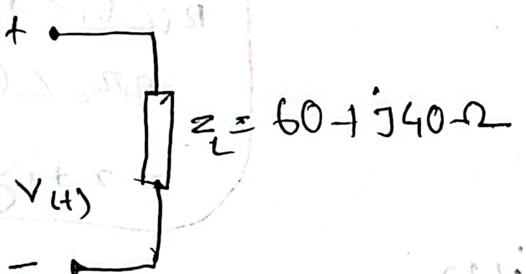
$$P = V_{rms} \cdot I_{rms} \cos(\theta_v - \theta_i)$$

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

$$Q = V_{rms} I_{rms} \sin(\theta_v - \theta_i)$$

$$= \frac{V_m I_m}{2} \sin(\theta_v - \theta_i)$$

$v(t) = 320 \cos(377t + 10°)$



$i(t) = ?$

$P_L = ?$

$Q_L = ?$

$pf = ?$

$S = ?$

$V = IZ \Rightarrow I = \frac{V}{Z_L}$

$$= \frac{320\angle 10°}{60 + j40}$$

$$= 4.43 \angle -23.7°\ A$$

$$= 4.43 \cos(377t - 23.7°)$$

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

$$= \frac{320 \times 4.43}{2} \cos(10 + 23.7°)$$

$$= 589.68\ W$$

Q_L

$$\frac{320 \times 4.43}{2} \sin(10 + 23.7)$$

$$= 393.27\ \text{VAR}$$

$S_L = P + jQ = |S_L| = \sqrt{P^2 + Q^2}$

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

$= \frac{320 \times 4.43}{2}$

$pf = \cos(\theta_v - \theta_i)$

$= \cos(10 + 23.7)$

$= 0.83$

11.4, 11.5

Example – 11.9 – 11.10

PP – 11.9 – 16.10

Ex – 38, 39, 41