(1)

$V_{rms} = 220\,V$, $f = 60\,Hz$, $I_{rms} = 20\,A$

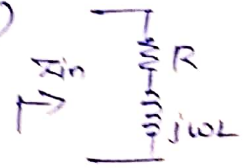
$Pf = 0.75$ (lagging) $= \cos\phi$ $\qquad \phi = \cos^{-1}(0.75) = 41.40^\circ$

a) Average power absorbed $= V_{rms} \times I_{rms} \times \cos\phi$

$= 220 \times 20 \times 0.75$

$= 3.3\,KW$

b)



$Z_{in} = R + j\omega L = \left|\frac{V_{rms}}{I_{rms}}\right| \angle\phi$

$= \left|\frac{220}{20}\right| \angle 41.40^\circ$

$= 11 \angle 41.40^\circ$

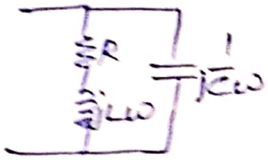
$R + j\omega L = 8.25 + j\,7.27$

Comparing on both sides

$R = 8.25\,\Omega$

$\omega L = 7.27\,\Omega$

$L = \frac{7.27}{2\pi f} = \frac{7.27}{2\pi \times 60} = 19.3\,mH$



If Pf is unity, impedance looking into input terminals is purely resistive

$Y = \frac{1}{R + j\omega L} + j\omega C$

$= \frac{R - j\omega L}{R^2 + (\omega L)^2} + j\omega C = \frac{R}{R^2 + (\omega L)^2} + j\left(\omega C - \frac{\omega L}{R^2 + (\omega L)^2}\right)$

equating imaginary part to zero,

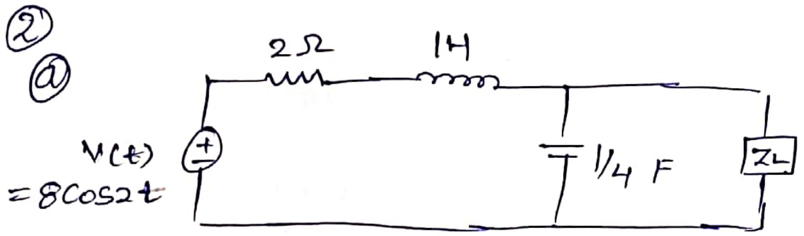
$\omega C = \frac{\omega L}{R^2 + \omega^2 L^2}$

$R^2 C + \omega^2 L^2 C = L$

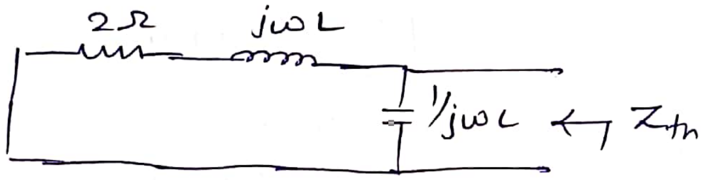
$C = \frac{19.3 \times 10^{-3}}{(8.25)^2 + (2\pi \times 60)^2 (19.3 \times 10^{-3})^2}$

$\therefore C = 0.135\,\mu F$

② ⓐ



~~Dividing~~ Evaluating thevenin equivalent impedance of the circuit by disconnecting the load and shorting the Voltage source



$$Z_{th} = (2 + j\omega L) \parallel \frac{1}{j\omega C}$$

$$= (2 + j\omega) \parallel \frac{4}{j\omega}$$

$$= (2 + j2) \parallel \frac{2}{j} = \frac{(2+2j)(-2j)}{2+2j-2j} = -2j + 2$$

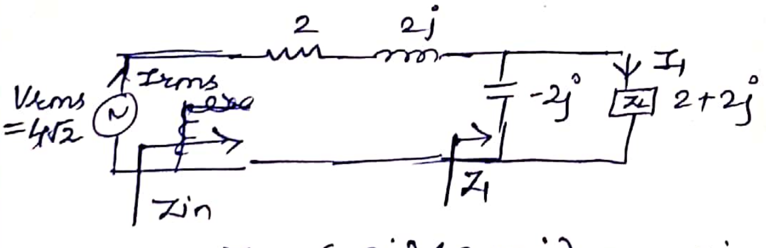
For maximum power transfer, $Z_L = Z_{th}^*$

$\therefore Z_L = 2 + 2j$

ⓑ for maximum power transfer

$$R_L = \sqrt{2^2 + 2^2} = 2\sqrt{2}\ \Omega$$

lets calculate maximum power absorbed by R_L



$$Z_1 = \frac{(-2j)(2+2j)}{2+2j-2j} = -2j + 2$$

$$Z_{in} = 2 + 2j + Z_1 = 2 + 2j - 2j + 2 = 4$$

$$I_{rms} = \frac{V_{rms}}{Z_{in}} = \frac{4\sqrt{2}}{4} = \sqrt{2}\ A$$

$$I_1 = \sqrt{2} \times \frac{(-2j)}{(2+2j-2j)} = -\sqrt{2}j = \sqrt{2}\angle -90^\circ$$

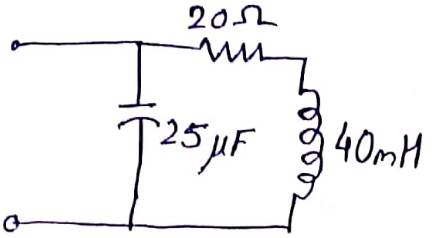
power absorbed by resistive load is

$$P_{abs} = I_1^2 \times R_L$$

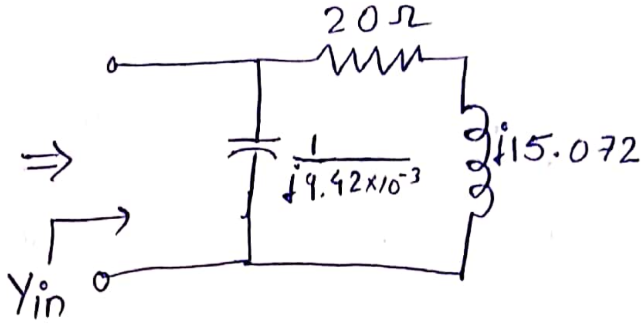
$$= (\sqrt{2})^2 \times 2 = 4\ W$$

Q 3

(a)



$\Rightarrow$



$$Y_{in} = j\,9.42\times10^{-3} + \frac{1}{20 + j15.072}$$

$$\Rightarrow Y_{in} = j\,9.42\times10^{-3} + \frac{20 - j15.072}{400 + 227.16}$$

$$\Rightarrow Y_{in} = j\,9.42\times10^{-3} + \frac{20}{627.16} - \frac{j15.072}{627.16} \Rightarrow \frac{20}{627.16} + j\left(9.42\times10^{-3} - \frac{15.072}{627.16}\right)$$

$$\Rightarrow Y_{in} = 31.89\times10^{-3} + j(-14.61\times10^{-3})$$

Now,

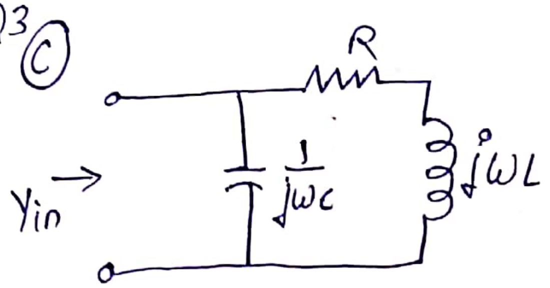
Power factor angle $\phi = \tan^{-1}\left(\frac{-14.61}{31.89}\right) = \underline{\underline{-24.61^\circ}}$

So, Power factor $\Rightarrow \cos\phi = \cos(-24.61) = \underline{\underline{0.9091}}$.

Q3

(b) For $Y_{in} = \frac{I}{V}$, Power factor angle is coming out to be -24.61°, which suggests that current is lagging behind voltage by 24.61°.

Q3 (c)



$$\Rightarrow Y_{in} = j\omega C + \frac{1}{R + j\omega L}$$

$$= j\omega C + \frac{R - j\omega L}{R^2 + (\omega L)^2}$$

$$= j\left(\omega C - \frac{\omega L}{R^2 + (\omega L)^2}\right) + \frac{R}{R^2 + (\omega L)^2}$$

Now, for power factor to be '1', circuit should be purely resistive.

$\therefore$ equating imaginary part to '0'

$$\Rightarrow \omega C - \frac{\omega L}{R^2 + (\omega L)^2} = 0 \Rightarrow C = \frac{L}{R^2 + (\omega L)^2}$$

$$C = \frac{40 \times 10^{-3}}{(20)^2 + (60 \times 40 \times 10^{-3})^2} \Rightarrow \boxed{C = 96.36\,\mu F}$$

Q5

(a) $V(t) + \int v\,dt = 10\cos t$

taking derivative on both sides

$\Rightarrow \dot{v}(t) + V(t) = -10\sin t$

~~Converting it into phasor form,~~

let $x(t) = -10\sin t$

$\Rightarrow \dot{v}(t) + v(t) = x(t)$

Converting to Phasor forms

$(j\omega+1)\,v(\omega) = x(\omega)$

$\frac{v(\omega)}{x(\omega)} = f(\omega) = \frac{1}{1+j\omega}$, $\because \omega = 1 \Rightarrow f(\omega) = \frac{1}{1+j}$

Now, $|f(\omega)| = \frac{1}{\sqrt{2}}$ & $\angle f(\omega) = -45°$

as i/p is sinusoidal, we can directly multiply $|f(\omega)|$ with magnitude of sinusoid & add their phases.

$\Rightarrow v(t) = -10 \times \left(\frac{1}{\sqrt{2}}\right)\sin(t - 45°)$

$\boxed{v(t) = 5\sqrt{2}\sin(t - 225°)}$

(b) $\frac{dv(t)}{dt} + 5v(t) + 4\int v(t)\,dt = 20\sin(4t + 10°)$

taking derivative on both sides

$\Rightarrow \ddot{v}(t) + 5\dot{v}(t) + 4v(t) = +80\cos(4t + 10°)$

Converting to phasor form.

$\Rightarrow v(\omega)\left[(j\omega)^2 + 5j\omega + 4\right] = x(\omega)$

$\Rightarrow \frac{V(\omega)}{x(\omega)} = \frac{1}{[(j\omega)^2 + 5j\omega + 4]} = \frac{1}{(1+j\omega)(1+4j\omega)}$

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After applying Partial fraction

$$\frac{V(\omega)}{X(\omega)} = \frac{-1}{3(1+j\omega)} + \frac{4}{3(1+j4\omega)}$$

$$\omega = 4 \Rightarrow \frac{V(\omega)}{X(\omega)} = \frac{-1}{3(1+j4)} + \frac{4}{3(1+j16)} = \frac{+1}{3} \times \frac{1\angle 180^\circ}{4.123\angle 75.96^\circ} + \frac{4}{3} \times \frac{1}{16.03\angle 86.42^\circ}$$

$$\frac{V(\omega)}{X(\omega)} = 80.84 \times 10^{-3} \angle 104.04 + 83.17 \times 10^{-3} \angle -86.42^\circ$$

$$\Rightarrow \frac{V(\omega)}{X(\omega)} = -0.0196 + j0.0784 + 5.19 \times 10^{-3} - j0.083$$

$$\Rightarrow \frac{V(\omega)}{X(\omega)} = -0.01441 + j\,4.6 \times 10^{-3}$$

$$= 0.0151 \angle -162.3$$

using same procedure as described in Q5@

$$v(t) = 20(0.0151)\sin(4t + 10^\circ - 162.3^\circ)$$

$$\boxed{v(t) = 0.302 \sin(4t - 152.3^\circ)}$$

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