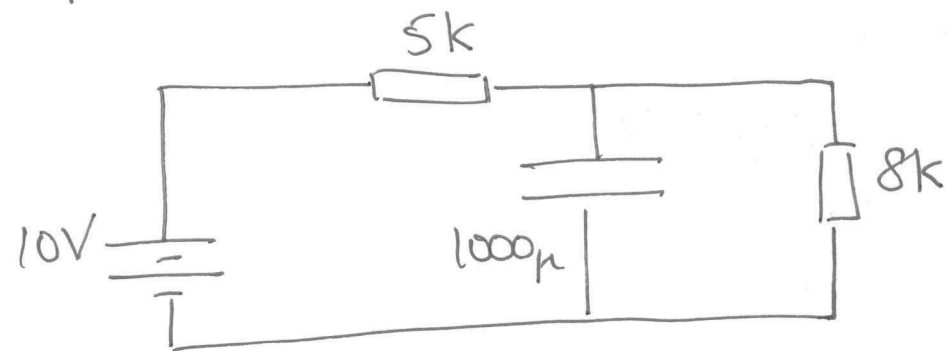


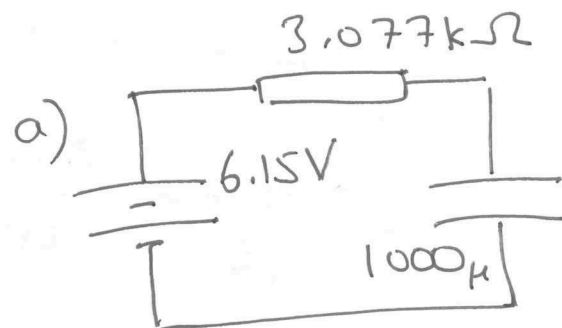
Q1.

4000 MAY'24
(MAIN)



$$R_T = \frac{5 \times 8}{13} = 3.077k$$

$$V = \left(\frac{8}{13}\right) 10 = 6.15V$$



b) i) $\tau = RC = 3077 \times 1000 \times 10^{-6} = 3 \text{ sec}$

ii) $5\tau = 5 \times 3 = 15 \text{ sec}$

$$I = \frac{V}{R} = \frac{6.15}{3077} = 1.99 \text{ mA} \approx 2 \text{ mA}$$

c) To reach 5V

i) $v = V(1 - e^{-t/\tau})$

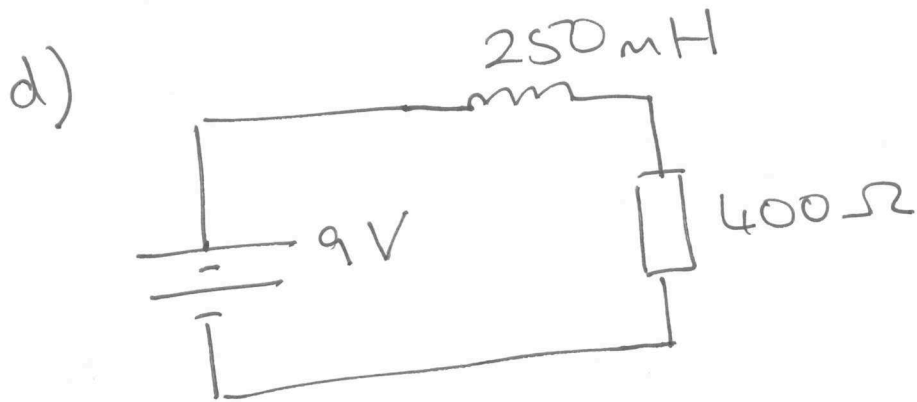
$$5 = 6.15(1 - e^{-t/3})$$

$$t = 3 \left[\ln \left(1 - \frac{5}{6.15} \right) \right] = 5 \text{ sec}$$

ii) $v = V(e^{-t/\tau})$

$$5 = 6.15(e^{-t/3})$$

$$t = 3 \ln \left(\frac{5}{6.15} \right) = 0.62 \text{ sec}$$



$$i) \tau = \frac{L}{R} = \frac{0.25}{400} = 0.625 \text{ msec}$$

$$5\tau = 3.125 \text{ msec}$$

$$ii) I = \frac{V}{R} = \frac{9}{400} = 0.0225 \text{ A} \\ = 22.5 \text{ mA}$$

$$iii) i = I(e^{-t/\tau})$$

$$t = \tau \ln\left(\frac{i}{I}\right) = 6.25 \times 10^{-4} \ln\left(\frac{20}{22.5}\right) \\ = 0.074 \text{ msec}$$

$$t = 6.25 \times 10^{-4} \ln\left(\frac{10}{22.5}\right) = 0.5 \text{ msec}$$

Q2 (a) $z_T = \left(\frac{z_1 z_2}{z_1 + z_2} \right) + z_3$

$$z_1 = 6 - j4 \quad z_2 = 3 + j5 \quad z_3 = 1.61 - j0.51$$

$$\begin{aligned} z_1 z_2 &= (6 - j4)(3 + j5) \\ &= 18 + j30 - j12 - j^2 20 \\ &= 38 + j18 \end{aligned}$$

$$\begin{aligned} z_1 + z_2 &= (6 - j4) + (3 + j5) \\ &= 9 + j \end{aligned}$$

$$\begin{aligned} \frac{z_1 z_2}{z_1 + z_2} &= \frac{38 + j18}{9 + j} \times \frac{9 - j}{9 - j} \\ &= \frac{342 - j38 + j162 - j^2 18}{9^2 + 1^2} \\ &= \frac{360 + j124}{82} = 4.39 + j1.51 \end{aligned}$$

$$\begin{aligned} \left(\frac{z_1 z_2}{z_1 + z_2} \right) + z_3 &= (4.39 + j1.51) + (1.61 - j0.51) \\ &= \cancel{5.79 - j5.69} \\ &= 6 + j \end{aligned}$$

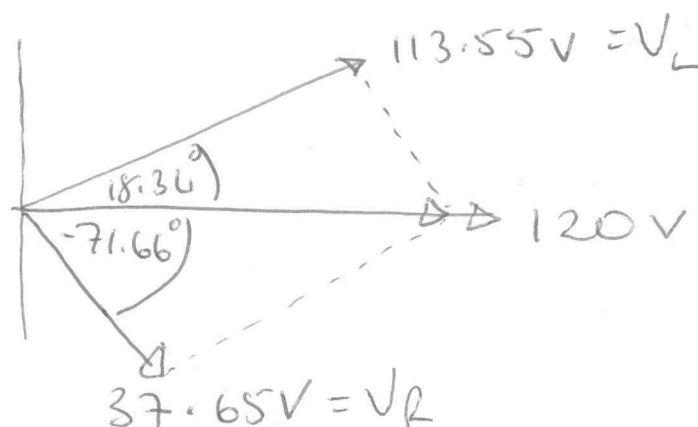
$$\begin{aligned}
 (b) \quad i) \quad Z &= (R + jX_L) & X_L &= 2\pi fL \\
 & & &= 2 \times 60 \times \pi \times 0.6 \\
 &= (75 + j226.19) \Omega & &= 226.19 \Omega \\
 &= 238.3 \angle 71.66^\circ \Omega
 \end{aligned}$$

$$ii) \quad I = \frac{V}{Z} = \frac{120 \angle 0^\circ}{238.3 \angle 71.66^\circ} = 0.502 \angle -71.66^\circ A$$

$$\begin{aligned}
 iii) \quad V_R &= IR = 0.502 \angle -71.66^\circ \times 75 \angle 0^\circ \\
 &= 37.65 \angle -71.66^\circ V
 \end{aligned}$$

$$\begin{aligned}
 V_L &= IX_L = 0.502 \angle -71.66^\circ \times 226.19 \angle 90^\circ \\
 &= 113.55 \angle 18.34^\circ V
 \end{aligned}$$

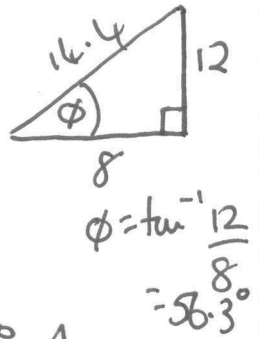
$$\begin{aligned}
 V &= V_R + V_L = (11.85 - j35.74) + (107.78 + j35.73) \\
 &= (119.63 - j0.04) \\
 &\approx 120 \angle 0^\circ V
 \end{aligned}$$



pf correction / 3φ

Q3

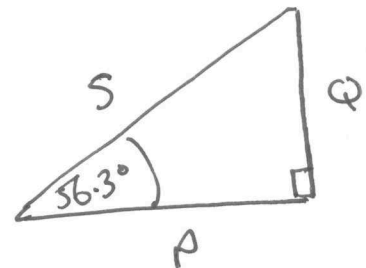
$$a) i) I = \frac{V}{Z} = \frac{50 \angle 30^\circ}{8 + j12} = \frac{50 \angle 30^\circ}{14.4 \angle 56.3^\circ} = 3.5 \angle -26.3^\circ A$$



$$ii) S = VI \quad (50 \angle 30^\circ)(3.5 \angle -26.3^\circ) \text{ No -ve lagging}$$

$$S = 175 \angle 36.3^\circ VA$$

$$S = P + jQ$$



$$P = VI \cos \phi$$

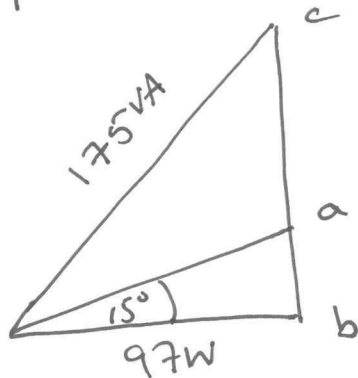
$$= 175 \cos(36.3^\circ) = 97.07 W$$

$$Q = VI \sin \phi$$

$$= 175 \sin(36.3^\circ) = 145.61 \text{ VAR}$$

$$iii) \cos \phi = 0.966$$

$$\phi = \cos^{-1} 0.966 = 14.98^\circ$$



145.6 VAR lagging

$$\tan 15^\circ = \frac{a}{97} = 26 \text{ VAR}$$

$$ca = 145.6 - 26 = 119.6 \text{ VAR lagging}$$

$$iv) I_c = \frac{Q_c}{V} = \frac{119.6}{50} = 2.392 A$$

$$X_c = \frac{V}{I_c} = \frac{50}{2.392} = 21 \Omega$$

$$X_c = \frac{1}{2\pi fC}$$

$$\therefore C = \frac{1}{2\pi fX_c} = \frac{1}{2\pi(2000)(21)}$$

$$\therefore C = 3.79 \mu F$$

Q3

(b) i) Current in each phase

$$\text{Power per phase} = \frac{21}{3} = 7 \text{ kW}$$

$$\text{kVA per phase} = \frac{7}{0.7} = 10 \text{ kVA} = \frac{P}{\cos \phi} = \frac{P}{\text{p.f.}}$$

$$I_{ph} = \frac{10000}{415} = 24.096 \text{ A} = \frac{\text{kVA}}{V}$$

$$\begin{aligned} I_{ph} &= 24.096 \cos^{-1}(0.7) \\ &= 24.096 \angle -45.57^\circ \text{ A} \quad \text{-ve because lagging.} \end{aligned}$$

$$I_{RY} = 24.09 \angle -45.57^\circ \text{ A}$$

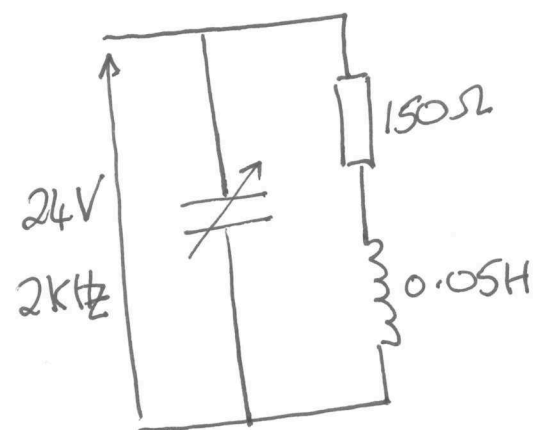
$$I_{YB} = 24.09 \angle -120 - 45.57^\circ = 24.09 \angle -165.57^\circ \text{ A}$$

$$I_{BR} = 24.09 \angle +120 - 45.57^\circ = 24.09 \angle 74.43^\circ \text{ A}$$

$$\begin{aligned} \text{ii) } I_L &= \sqrt{3} I_{ph} \\ &= \sqrt{3} \times 24.09 = 41.74 \text{ A} \end{aligned}$$

Q4 resonance

Resonant frequency $f_r = \frac{1}{2\pi} \sqrt{\left(\frac{1}{LC} - \frac{R^2}{L^2}\right)}$



$$\begin{aligned} \therefore C &= \frac{1}{L \left((2\pi f_r)^2 + \left(\frac{R^2}{L^2} \right) \right)} \\ &= \frac{1}{0.05 \left((2\pi \times 2000)^2 + \left(\frac{150^2}{0.05^2} \right) \right)} \\ &= \frac{1}{0.05 (157.9 \times 10^6 + 9 \times 10^6)} \\ &= 119.8 \text{ nF} \end{aligned}$$

Dynamic resistance, $R_D = \frac{L}{CR} = \frac{0.05}{(119.8 \times 10^{-9} \times 150)} = 2781.9 \Omega$

$I_r = \frac{V}{R_D} = \frac{24}{2781.9} = 8.63 \text{ mA}$ lowest at resonance

Q factor at resonance $Q_r = \frac{\omega_r L}{R} = \frac{(2\pi \times 2000) \times 0.05}{150} = 4.19$

Upper and lower -3dB frequencies are f_1 and f_2

Bandwidth $= (f_2 - f_1)$

$Q_r = \frac{f_r}{(f_2 - f_1)} \therefore (f_2 - f_1) = \frac{f_r}{Q_r} = \frac{2000}{4.19} = 477.46 \text{ Hz}$

$f_r = \sqrt{f_1 f_2} \therefore f_1 f_2 = f_r^2 = 2000^2 = 4 \times 10^6 \text{ Hz}$

Also $f_1 = \frac{f_r^2}{f_2}$ so Bandwidth $f_2 - \frac{f_r^2}{f_2} = 477.46$

$\therefore f_2^2 - f_r^2 = 477.46 f_2$

Q4 cont.

$$f_2^2 - 477.46 f_2 - 4 \times 10^6 = 0$$

This quadratic can be solved using:

$$\frac{-b \pm \sqrt{b^2 - 4ac}}{2a}$$

where $a = 1$, $b = -477.46$
 $c = -4 \times 10^6$

$$f_2 = \frac{477.46 \pm \sqrt{(-477.46)^2 - 4(1)(-4 \times 10^6)}}{2(1)}$$

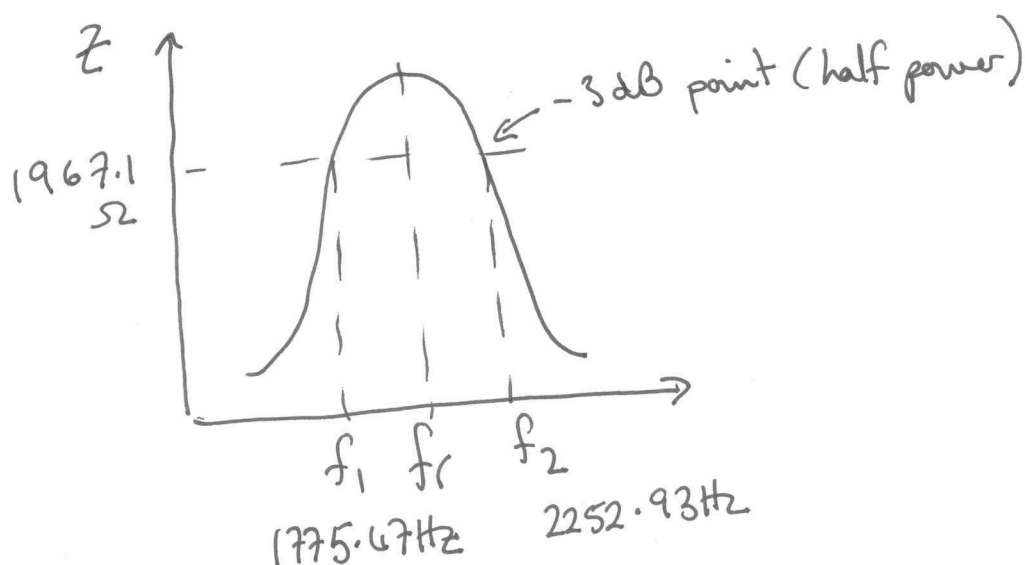
$$= \frac{477.46 \pm 4028}{2} = 2252.93 \text{ Hz}$$

(neglect -ve value)

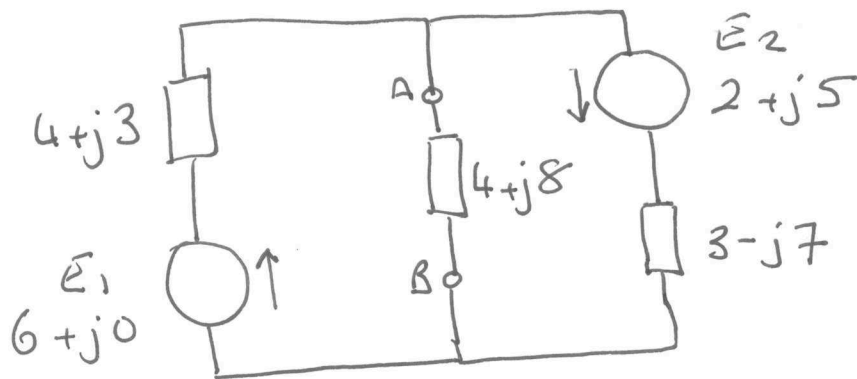
$$f_1 = \frac{f_r^2}{f_2} = \frac{4 \times 10^6}{2252.93} = 1775.47 \text{ Hz}$$

Z at -3dB frequencies

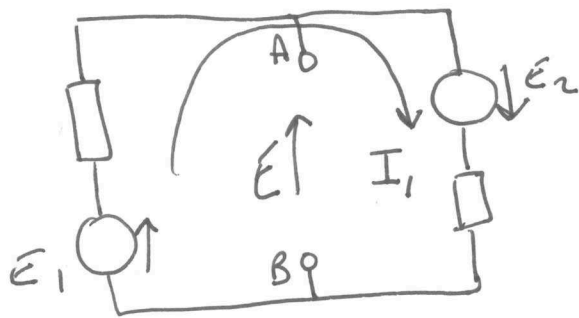
$$Z = \frac{1}{\sqrt{2}} \times Z_r \text{ where } Z_r = R_D = 2781.9 \Omega$$
$$= \frac{1}{\sqrt{2}} \times 2781.9 = 1967.1 \Omega$$



Q5
Thevenin



• Remove the $4 + j8$ impedance



$$I_1 = \frac{(6 + j0) + (2 + j5)}{(4 + j3) + (3 - j7)}$$

$$= \frac{8 + j5}{7 - j4} = \frac{9.43 \angle 32^\circ}{8.06 \angle -29.74^\circ}$$

$$= 1.17 \angle 61.74^\circ \text{ A}$$

$$E = E_1 - I_1(4 + j3)$$

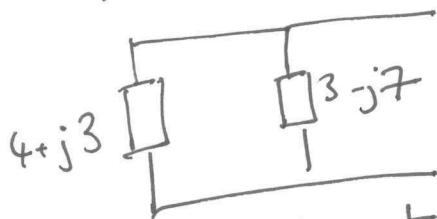
$$= (6 + j0) - (1.17 \angle 61.74^\circ \times 5 \angle 36.87^\circ)$$

$$= (6 + j0) - 5.85 \angle 98.61^\circ$$

$$i) = (6 + j0) - (-0.876 + j5.78) = 6.876 - j5.78$$

$$= 8.98 \angle -40^\circ \text{ V}$$

• Remove sources

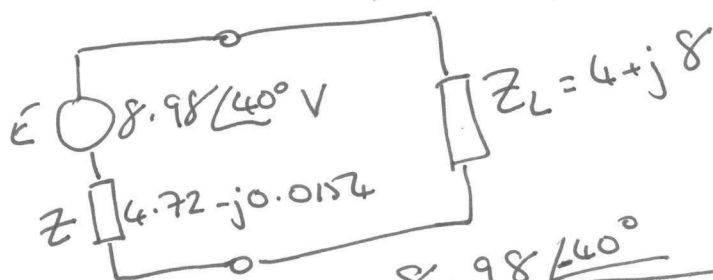


$$Z = \frac{(4 + j3)(3 - j7)}{(4 + j3) + (3 - j7)} = \frac{12 - j19 - j^2 21}{7 - j4}$$

$$= \frac{33 - j19}{7 - j4} \times \frac{7 + j4}{7 + j4}$$

$$= \frac{231 + j132 - j133 - j^2 76}{7^2 + 4^2}$$

• Thevenin Eq cct. iii)



$$I_L = \frac{E}{Z_L + Z} = \frac{8.98 \angle -40^\circ}{(4.72 - j0.0154) + (4 + j8)}$$

$$ii) = \frac{307 - j}{65}$$

$$= 4.72 - j0.0154 \Omega$$

$$= \frac{8.98 \angle -40^\circ}{8.72 + j7.985}$$

$$= \frac{8.98 \angle -40^\circ}{11.82 \angle 47.52^\circ}$$

$$iv) = 0.76 \angle -87.52^\circ \text{ A}$$