EE 201 - THEORY OF ELECTRICITY – Short Answers

Level 2 Semester 1 Examination - March 2005

1. (a) volume = V, lamination thickness = t, alternating flux density peak value = B_m, frequency = f.

total core loss = P, hysteresis loss P_h = eddy current loss P_e = P/2

if changed to 0.6V, 0.5t, B_m, 1.2f,

new hysteresis loss $= P_h \times$ volume ratio $\times$ frequency ratio $= P/2 \times 0.6 \times 1.2 = 0.36\ P$

new eddy current loss $= P_e \times$ volume ratio $\times$ thickness ratio^2 $\times$ frequency ratio^2

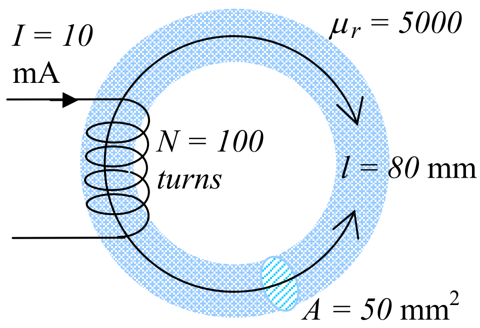
$= P/2 \times 0.6 \times 0.5^2 \times 1.2^2 = 0.108\ P$

$\therefore$ total loss in the core $= 0.36\ P + 0.108\ P =$ <u>**0.468 P**</u>

2 marks

(b) Reluctance $S = l/\mu A$

$$= \frac{80\times10^{-3}}{4\pi\times10^{-7}\times5000\times50\times10^{-6}} = \underline{254{,}648\ H^{-1}}$$



Inductance $L = N^2/S = 100^2/254648 = \underline{0.0393\ H}$

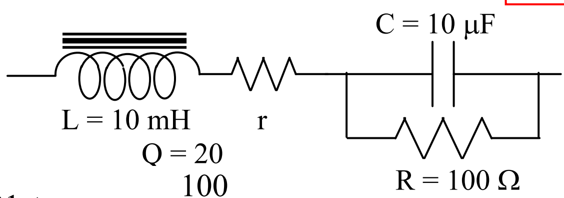
$L\,I = N\,\phi$

gives $\phi = L\,I/N = \dfrac{0.0393\times10\times10^{-3}}{100} = 3.93\ \mu Wb$

flux density $B = \phi/A = \dfrac{3.93\times10^{-6}}{50\times10^{-6}} = \underline{\mathbf{0.0786\ T}}$

2 marks

(c) for the inductor, Q = 20 at 50 Hz



$\therefore\ r = L\omega/Q = \dfrac{10\times10^{-3}\times2\pi\times50}{20} = 0.157\ \Omega$

i.e. $Z = r + j\,\omega L + \dfrac{R}{1+j\omega CR} = 0.157 + j\,\omega\,0.01 + \dfrac{100}{1+j\omega\times10\times10^{-6}\times100}$

For unity power factor resonance condition, real part of Z must be zero.

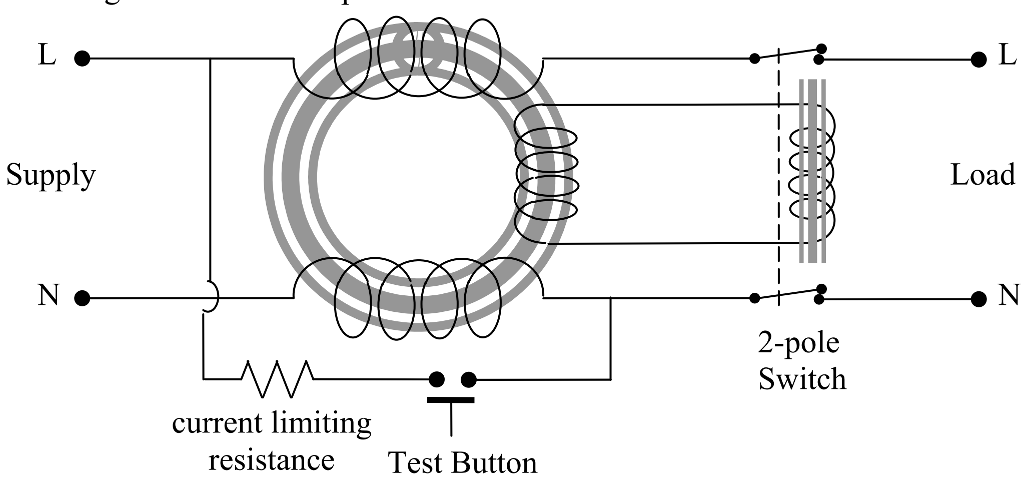
$\therefore\ \omega\,0.01 - j\dfrac{0.1\omega}{1^2+10^{-6}\omega^2} = 0$ gives $\omega = 0$, or $0.01 + 10^{-8}\,\omega^2 = 0.1$

Since $\omega \neq 0$, the resonant condition corresponds to ω = 3000 rad/s or f = <u>**477.5 Hz**</u>

Equivalent impedance at resonance $= 0.157 + \dfrac{100}{1+10^{-6}\times3000^2} = \underline{\mathbf{10.16\ \Omega}}$

4 marks

(d) Circuit diagram with brief explanation



2 marks

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2. (a) Applying Kirchoff's voltage law

$E = R_1.i + (j\omega L_1.i - j\omega M.i) + (1/j\omega C).i + (j\omega L_2.i - j\omega M.i) + R_2.i$

1 marks

(b) $Z = E/i = R_1 + R_2 + j\omega L_1 + j\omega L_2 - j2\omega M + 1/j\omega C$

1 marks

(c) $E = 230$ V, $f = 50$ Hz, $L_1 = 20$ mH, $R_1 = 15\ \Omega$, $R_2 = 10\ \Omega$, $C = 50\ \mu$F, $L_2 = 30$ mH, $M = 20$ mH

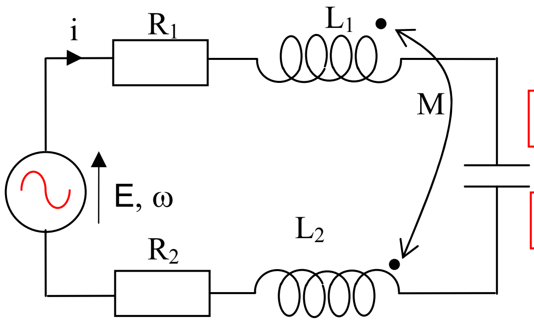

Figure Q2

$\omega = 2\pi \times 50 = 314.16$ rad/s

$Z = 15 + 10 + j\ 314.16\times(0.02 + 0.03 - 2\times 0.02) - j\ /(314.16\times 50\times 10^{-6})$

$= 25 + j\ 3.142 - j\ 63.66 = \underline{25 - j\ 60.52\ \Omega}$ or $\underline{65.48\angle -67.6^o\ \Omega}$.

2 marks

(d) $i = E/Z = 230\angle 0^o / 65.48\angle -67.6^o = \underline{3.51\angle 67.6^o}$

1 marks

(e) power factor = $\cos 67.6^o = \underline{0.38 \text{ lead}}$

active power supplied = $230 \times 3.51 \times 0.38 = \underline{307.6 \text{ W}}$

1 marks

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3. (a) $L_1 = 100$ mH, $C_2 = 50\ \mu$F, $R = 10\ \Omega$, $L = 30$ mH, $R_3 = R_4 = 20\ \Omega$

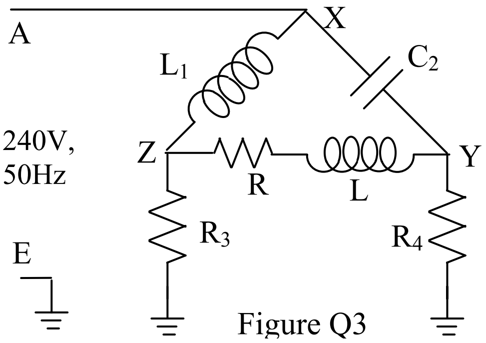
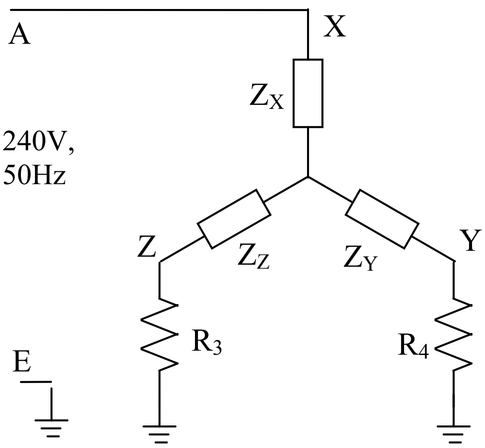


Figure Q3



at 50 Hz,

$L_1 \rightarrow j\times 100\pi\times 100\times 10^{-3} = j31.416\ \Omega$,

$L \rightarrow j\times 100\pi\times 30\times 10^{-3} = j9.424\ \Omega$

$C_2 \rightarrow 1/j\times 100\pi\times 50\times 10^{-6} = -j\ 63.66\ \Omega$

Using the delta-star transformation theorem

$$Z_X = \frac{Z_{XY}Z_{XZ}}{Z_{XY} + Z_{XZ} + Z_{YZ}}, \text{ similarly } Z_Y, Z_Z$$

$$Z_X = \frac{(-j63.66)(j31.416)}{-j63.66 + 10 + j9.424 + j31.416} = \frac{2000}{10 - j22.82} = \frac{2000}{24.91\angle -66.34^o} = \underline{80.29\angle 66.3^o\ \Omega},$$

$$Z_Y = \frac{(-j63.66)(10 + j9.424)}{-j63.66 + 10 + j9.424 + j31.416} = \frac{63.66\angle -90^o \times 13.74\angle 43.30^0}{24.91\angle -66.34^o} = \frac{874.68\angle -46.70^o}{24.91\angle -66.34^o}$$

$= \underline{35.11\angle 19.6^o\ \Omega}$

$$Z_Z = \frac{(j31.416)(10 + j9.424)}{-j63.66 + 10 + j9.424 + j31.416} = \frac{31.416\angle 90^o \times 13.74\angle 43.30^0}{24.91\angle -66.34^o} = \frac{431.66\angle 133.30^o}{24.91\angle -66.34^o}$$

$= \underline{17.33\angle 199.6^o\ \Omega}$

3 marks

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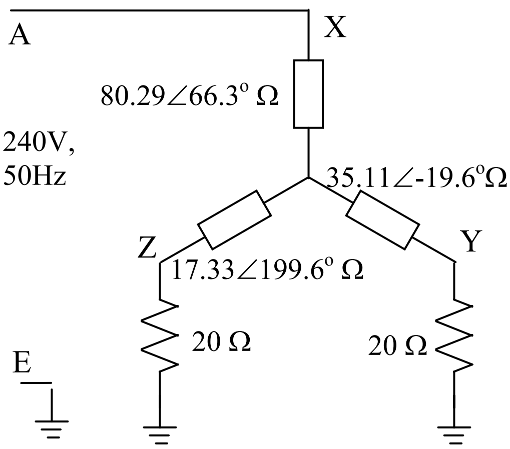
(b) Total impedance = $Z_X + (Z_Y + 20) // (Z_Z + 20)$



$= 80.29\angle 66.3^o + (35.11\angle 19.6^o + 20)//(17.33\angle 199.6^o + 20)$

$= 32.28 + j\,73.53 + (53.075 + j\,11.777)//(3.674 - j\,5.813)$

$$= 32.28 + j\,73.53 + \frac{(53.075 + j11.777)\times(3.674 - j5.813)}{53.075 + j11.777 + 3.674 - j5.813}$$

$$= 32.28 + j\,73.53 + \frac{54.367\angle 12.51^0 \times 6.877\angle -57.71^0}{57.062\angle 6.00^0}$$

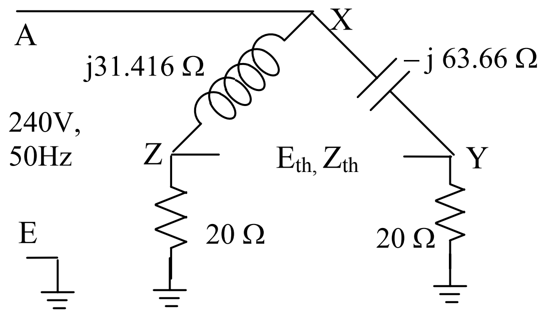
$$= 32.28 + j\,73.53 + \frac{373.88\angle -45.20^0}{57.062\angle 6.00^0}$$

$= 32.28 + j73.53 + 6.552\angle\text{-}51.20^o = 32.28 + j73.53 + 4.11 - j5.11 = 36.39 + j\,68.42 = 77.50\angle 62.0^0\,\Omega$

∴ current supplied = $240\angle 0^o/77.50\angle 62.5^0$ = $\underline{\underline{3.097\angle\text{-}62.0^0\ A}}$

3 marks

(c)



$Z_{th} = 20//j31.416 + 20//\text{-}j63.66$

$$= \frac{20\times j31.416}{20 + j31.416} + \frac{20\times(-j63.66)}{20 - j63.66}$$

$$= \frac{628.32\angle 90^0}{37.24\angle 57.52^0} + \frac{1273.2\angle -90^0}{66.73\angle -72.56^0}$$

$= 16.872\angle 32.48^o + 19.080\angle -17.44^o$

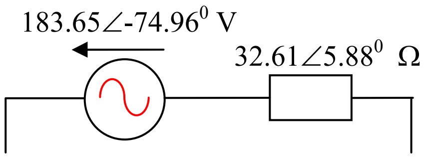
$= 14.233 + j\,9.060 + 18.203 - j\,5.718 = 32.436 + j\,3.342 = 32.61\angle 5.88^0\ \Omega$

$$E_{th,\,ZY} = 240\times\frac{20}{20 + j31.416} - 240\times\frac{20}{20 - j63.66} = 240\times\frac{20}{37.24\angle 57.52^0} - 240\times\frac{20}{66.73\angle -72.56^0}$$

$= 128.89\angle\text{-}57.52^o - 71.932\angle 72.56^o = 69.215 - j\,108.73 - 21.559 - j\,68.625$

$= 47.66 - j\,177.36 = 183.65\angle\text{-}74.96^0$ V

Thus the Thevenin's equivalent circuit across ZY is



3 marks

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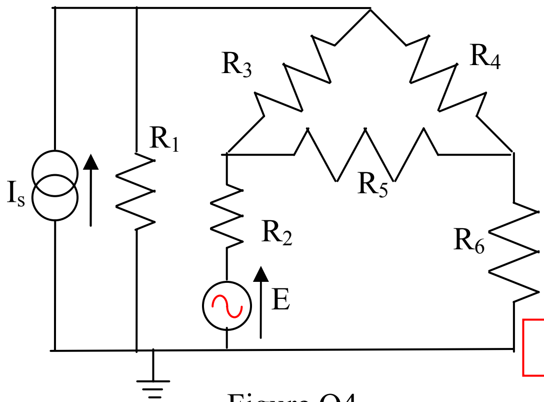
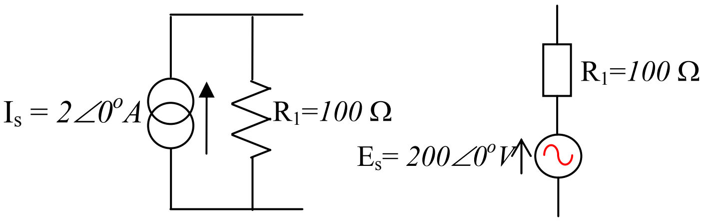
4 $I_s = 2\angle 0^o A$, $E = 100\angle 30^o\ V$, $\omega = 250$ rad/s for both supplies, $R_1 = R_3 = R_4 = R_5 = 100\ \Omega$, $R_2 = R_6 = 200\ \Omega$



1 marks

Figure Q4

(a) Converted circuit is shown



(b)

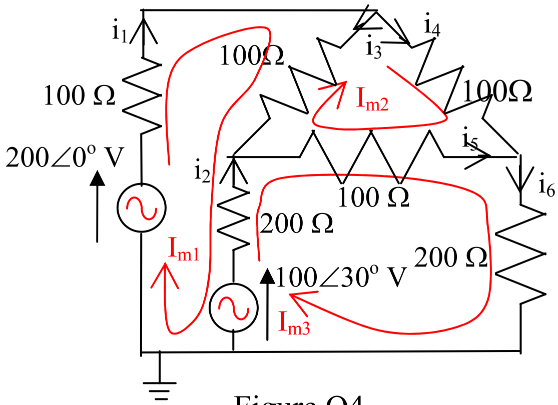


Figure Q4

branch impedance matrix

$$[Z_b] = \begin{bmatrix} 100 & 0 & 0 & 0 & 0 & 0 \\ 0 & 200 & 0 & 0 & 0 & 0 \\ 0 & 0 & 100 & 0 & 0 & 0 \\ 0 & 0 & 0 & 100 & 0 & 0 \\ 0 & 0 & 0 & 0 & 100 & 0 \\ 0 & 0 & 0 & 0 & 0 & 200 \end{bmatrix}$$

mesh-branch incidence matrix

$$= \begin{bmatrix} 1 & -1 & 1 & 0 & 0 & 0 \\ 0 & 0 & -1 & 1 & -1 & 0 \\ 0 & 1 & 0 & 0 & 1 & 1 \end{bmatrix}$$

mesh voltage source $$[E_m] = \begin{bmatrix} 200\angle 0^0 - 100\angle 30^0 \\ 0 \\ 100\angle 30^0 \end{bmatrix} = \begin{bmatrix} 113.40 - j50 \\ 0 \\ 100\angle 30^0 \end{bmatrix} = \begin{bmatrix} 123.9\angle -23.8^0 \\ 0 \\ 100\angle 30^0 \end{bmatrix}$$

3 marks

(c) mesh impedance matrix $[Z_m]$

$$= \begin{bmatrix} 1 & -1 & 1 & 0 & 0 & 0 \\ 0 & 0 & -1 & 1 & -1 & 0 \\ 0 & 1 & 0 & 0 & 1 & 1 \end{bmatrix} \begin{bmatrix} 100 & 0 & 0 & 0 & 0 & 0 \\ 0 & 200 & 0 & 0 & 0 & 0 \\ 0 & 0 & 100 & 0 & 0 & 0 \\ 0 & 0 & 0 & 100 & 0 & 0 \\ 0 & 0 & 0 & 0 & 100 & 0 \\ 0 & 0 & 0 & 0 & 0 & 200 \end{bmatrix} \begin{bmatrix} 1 & 0 & 0 \\ -1 & 0 & 1 \\ 1 & -1 & 0 \\ 0 & 1 & 0 \\ 0 & -1 & 1 \\ 0 & 0 & 1 \end{bmatrix}$$

i.e. $[Z_m] = \begin{bmatrix} 400 & -100 & -200 \\ -100 & 300 & -100 \\ -200 & -100 & 500 \end{bmatrix}$, $[Z_m]^{-1} = \dfrac{1}{\Delta}\begin{bmatrix} 140000 & 70000 & 70000 \\ 70000 & 160000 & 60000 \\ 70000 & 60000 & 110000 \end{bmatrix}$

3 marks

where $\Delta = 400\times 140000 - 100\times 70000 - 200\times 70000 = 35000000$

(d) i.e. $$\begin{bmatrix} 123.9\angle -23.8^0 \\ 0 \\ 100\angle 30^0 \end{bmatrix} = \begin{bmatrix} 400 & -100 & -200 \\ -100 & 300 & -100 \\ -200 & -100 & 500 \end{bmatrix} \begin{bmatrix} I_{m1} \\ I_{m2} \\ I_{m3} \end{bmatrix}$$

i.e. $$\begin{bmatrix} I_{m1} \\ I_{m2} \\ I_{m3} \end{bmatrix} = \begin{bmatrix} 0.004 & 0.002 & 0.002 \\ 0.002 & 0.00457 & 0.00171 \\ 0.002 & 0.00171 & 0.00314 \end{bmatrix} \begin{bmatrix} 123.9\angle -23.8^0 \\ 0 \\ 100\angle 30^0 \end{bmatrix}$$

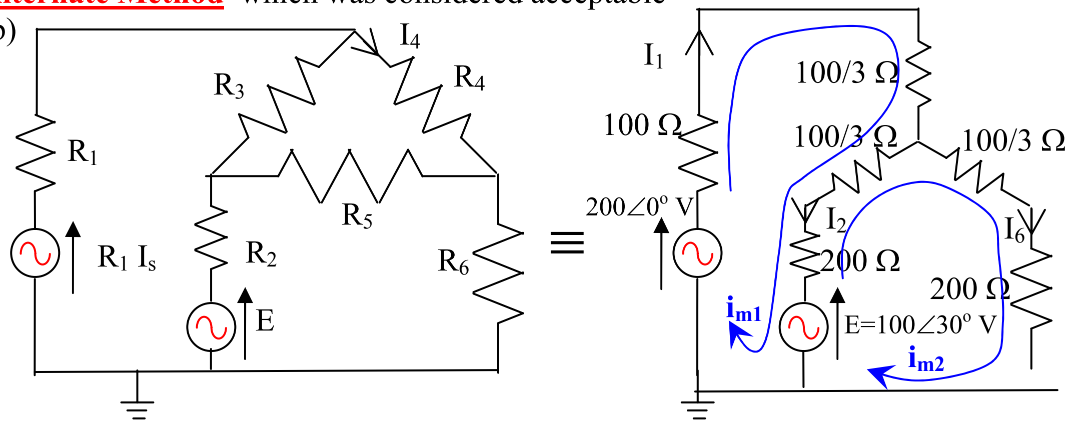
$\therefore$ current in resistor $R_4 = i_4 = I_{m2} = (0.2267 - j\ 0.1000) + 0 + (0.1481 + j0.0855)$

3 marks

$= 0.3748 - j\ 0.0145 = \underline{0.375\angle -2.2^0\ A}$

Alternate Method which was considered acceptable

(b)



convert the delta connection of R_3, R_4 and R_5 to an equivalent star as shown write down branch impedance matrix and mesh-branch incidence matrix

$$[Z_b] = \begin{bmatrix} \frac{400}{3} & 0 & 0 \\ 0 & \frac{700}{3} & 0 \\ 0 & 0 & \frac{700}{3} \end{bmatrix}, \ [B]^T = \begin{bmatrix} 1 & 1 & 0 \\ 0 & -1 & 1 \end{bmatrix} \text{ and}$$

$$\text{mesh voltage source} [E_m] = \begin{bmatrix} 200\angle 0^0 - 100\angle 30^0 \\ 100\angle 30^0 \end{bmatrix} = \begin{bmatrix} 113.40 - j50 \\ 100\angle 30^0 \end{bmatrix} = \begin{bmatrix} 123.9\angle -23.8^0 \\ 100\angle 30^0 \end{bmatrix}$$

(c) mesh impedance matrix $[Z_m]$

$$= \begin{bmatrix} 1 & 1 & 0 \\ 0 & -1 & 1 \end{bmatrix} \begin{bmatrix} \frac{400}{3} & 0 & 0 \\ 0 & \frac{700}{3} & 0 \\ 0 & 0 & \frac{700}{3} \end{bmatrix} \begin{bmatrix} 1 & 0 \\ 1 & -1 \\ 0 & 1 \end{bmatrix} = \begin{bmatrix} \frac{1100}{3} & -\frac{700}{3} \\ -\frac{700}{3} & \frac{1400}{3} \end{bmatrix}$$

$\Delta = 1100 \times 1400/9 - 700 \times 700/9 = 350000/3$

$$[Z_m]^{-1} = \frac{1}{\Delta} \begin{bmatrix} \frac{1400}{3} & \frac{700}{3} \\ \frac{700}{3} & \frac{1100}{3} \end{bmatrix} = \begin{bmatrix} 0.004 & 0.002 \\ 0.002 & 0.00314 \end{bmatrix}$$

(d) i.e.
$$\begin{bmatrix} I_{m1} \\ I_{m2} \end{bmatrix} = \begin{bmatrix} 0.004 & 0.002 \\ 0.002 & 0.00314 \end{bmatrix} \begin{bmatrix} 123.9\angle -23.8^0 \\ 100\angle 30^0 \end{bmatrix} = \begin{bmatrix} 0.626 - j0.1 \\ 0.499 + j0.0573 \end{bmatrix}$$

The branch current I_4 may then be obtained from equating voltage drop across R_4

$$\text{i.e. } 100 I_4 = \frac{100}{3} i_{m1} + \frac{100}{3} I_{m2} = \frac{100}{3}(0.626 - j0.1 + 0.499 + j0.0573)$$

i.e. $I_4 = 0.375 - j\,0.0142 = 0.375 \angle 2.2^o$ A

5

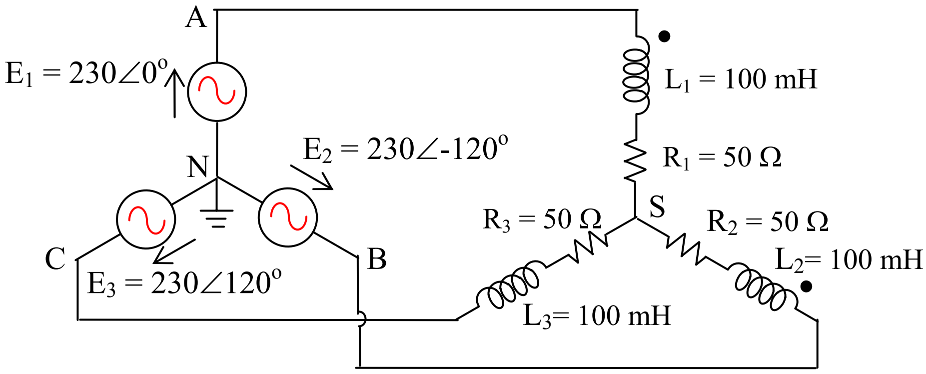


Figure Q5

(a) If no mutual inductance exists, for a balanced source and balanced load, star point voltage is equal to the neutral voltage. Thus considering one phase only, V = 400/√3 = 230.9 V

phase A current $= \dfrac{230.9\angle 0^0}{50 + j0.10\times 100\pi} = \dfrac{230.9\angle 0^0}{59.05\angle 32.14^0} = \underline{\underline{3.91\angle\text{-}32.14^0\ \text{A}}}$

phase B and phase C currents are displaced by $\pm 120^0$

phase B current = $\underline{\underline{3.91\angle\text{-}152.14^0\ \text{A}}}$

phase C current = $\underline{\underline{3.91\angle 87.86^0\ \text{A}}}$

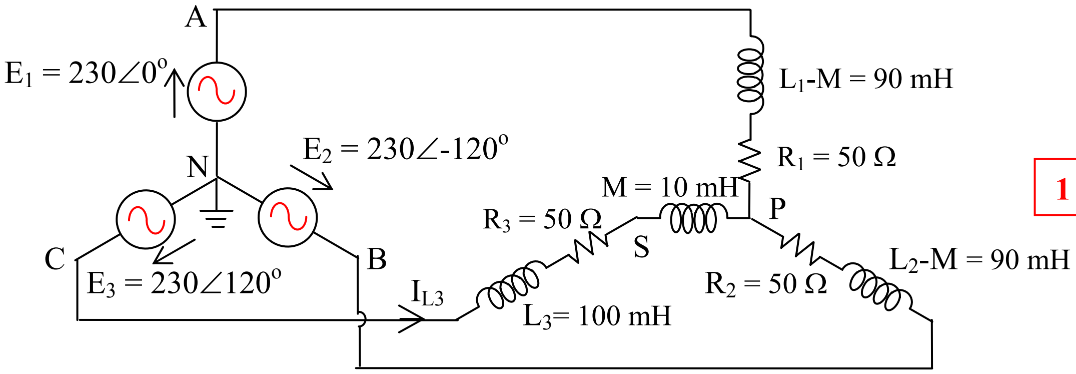
2 marks

(b) power factor of load = cos 32.14^0 = $\underline{\underline{0.8467\text{ lag}}}$

1 marks

active power supplied = √3 × 400 × 3.91 × 0.8467 = $\underline{\underline{2293\text{ W}}}$ (or 3 × 3.91^2 × 50 = 2293 W)

(c)



1 marks

(d) 100 mH → 0.10 ×100π = 31.416 Ω, 10 mH → 3.142 Ω, 90 mH → 28.274 Ω

Using Millmann's theorem

$$V_{PN} = \frac{\sum Y.V}{\sum Y} = \frac{\dfrac{230.9\angle 0^0}{50 + j28.274} + \dfrac{230.9\angle -120^0}{50 + j28.274} + \dfrac{230.9\angle 120^0}{50 + j34.557}}{\dfrac{1}{50 + j28.274} + \dfrac{1}{50 + j28.274} + \dfrac{1}{50 + j34.557}}$$

$$= \frac{\dfrac{230.9\angle 0^0}{57.440\angle 29.487} + \dfrac{230.9\angle -120^0}{57.440\angle 29.487} + \dfrac{230.9\angle 120^0}{60.780\angle 34.650}}{0.0174\angle -29.487^0 + 0.0174\angle -29.487^0 + 0.0165\angle -34.650^0}$$

$$= \frac{4.020\angle -29.487^0 + 4.020\angle -149.487^0 + 3.799\angle 85.350}{0.0174\angle -29.487^0 + 0.0174\angle -29.487^0 + 0.0165\angle -34.650^0}$$

$$= \frac{3.500 - j1.979 - 3.463 - j2.041 + 0.3080 + j3.7865}{0.0151 - j0.00856 + 0.0151 - j0.00856 + 0.01357 - j0.00938}$$

$$= \frac{0.345 - j0.234}{0.0437 - j0.0265} = \frac{0.417\angle -34.14^0}{0.0511\angle -31.23^0} = \underline{\underline{8.16\angle\text{-}2.91^0\ V}}$$

5 marks

I_{L3} $= (230.9\angle 120^0 - 8.16\angle\text{-}2.91^0)\times 0.0165\angle\text{-}34.65^0 = 0.309 + j3.797 - 0.1067 + j\ 0.0821$

$= 0.202 + j\ 3.879 = \underline{3.884\angle 87.02^0\ A}$

(e) $V_{SN} = V_{PN} + j\omega M.\ I_{L3} = 8.16\angle\text{-}2.91^0 + j\ 100\pi\times 0.01\times 3.884\angle 87.02^0$

$= 8.149 - j\ 0.414 - 12.186 + j\ 0.635 = -4.037 + j\ 0.221 = \underline{\underline{4.04\angle 176.9^0\ V}}$

2 marks

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6 (a) z-parameter matrix

$$\begin{bmatrix} V_1 \\ V_2 \end{bmatrix} = \begin{bmatrix} z_{11} & z_{12} \\ z_{21} & z_{22} \end{bmatrix} \begin{bmatrix} I_1 \\ I_2 \end{bmatrix}$$

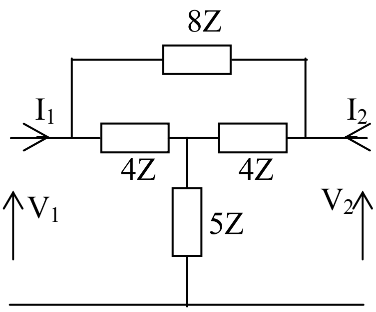


Figure Q6a

$$z_{11} = \left.\frac{V_1}{I_1}\right|_{I_2=0} = 12Z//4Z + 5Z = (12\times 4/16 + 5)Z = 8Z$$

$z_{22} = z_{11} = 8Z$

when $I_2 = 0$, I_1 divides itself in the proportion of 12Z:4Z in the two branches

$\therefore\ V_2 = V_1 - 8Z\times I_1/4 = 8Z\times I_1 - 8Z\times I_1/4 = 6Z\times I_1$

$$z_{21} = \left.\frac{V_2}{I_1}\right|_{I_2=0} = 6Z, \text{ giving the z-parameter matrix as } \begin{bmatrix} 8Z & 6Z \\ 6Z & 8Z \end{bmatrix}$$

4 marks

(b)

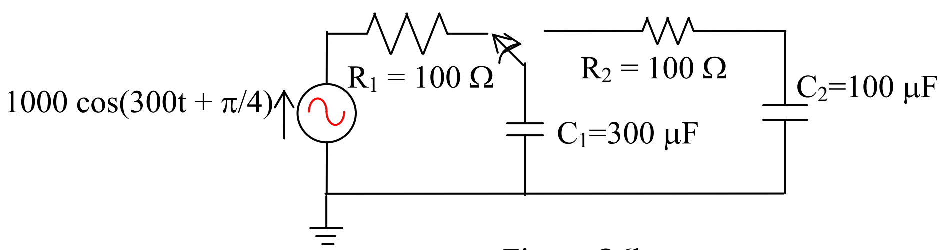


Figure Q6b

$C_1 \rightarrow 1/j\ 300\times 300\times 10^{-6} = -j\ 11.1111\ \Omega$

$\sqrt{2}\times$rms voltage across capacitor is $\frac{-j11.111\times 1000}{100 - j11.11} = \frac{11111\angle -90^0}{100.615\angle -6.34^0} = 110.4\angle -83.66^0$

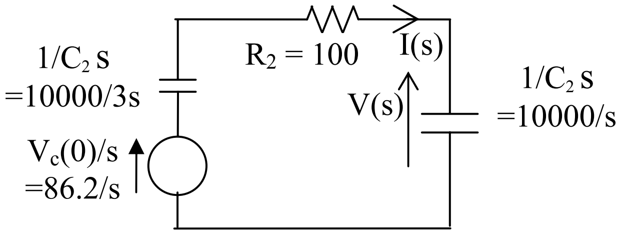
$\therefore$ Voltage across capacitor is given by $110.4\cos(300t + 45^0 - 83.66^0)$

or $v_c(t) = 110.4\cos(300t - 38.66^0)$

$\therefore\ v_c(0) = 110.4\cos 38.66^0 = 86.2$ V

3 marks

The transformed equivalent circuit is given by



Thus the circuit current can be calculated as

$$I(s) = \frac{\frac{86.2}{s}}{\frac{10000}{3s} + 100 + \frac{10000}{s}}$$

$$I(s) = \frac{258.6}{40000 + 300s}, \quad V(s) = \frac{1}{C_2 s} I(s) = \frac{10000}{s} \frac{258.6}{40000 + 300s} = \frac{8620}{s(s + 133.33)}$$

i.e. $V(s) = \dfrac{64.65}{s} - \dfrac{64.65}{s + 133.33}$

∴ voltage across C_2 is given by v(t) = $\underline{64.65(1 - e^{-133.33t})}$

3 marks

7

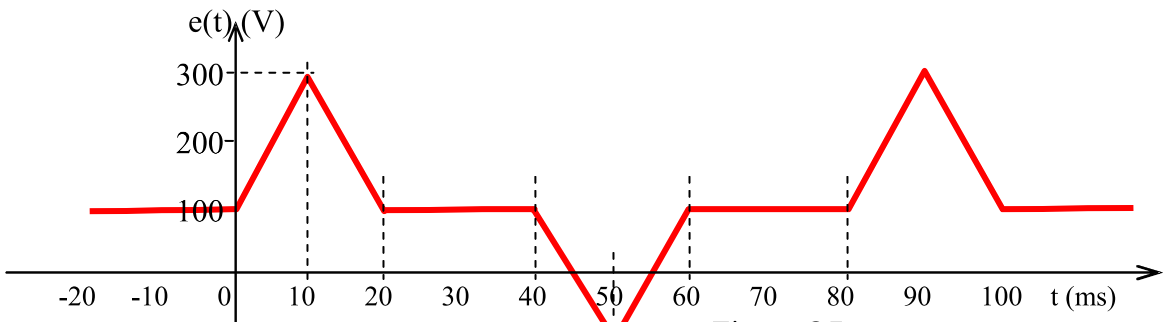


Figure Q7a

Period = 80 ms = 0.08 s, ω = 2π/0.08 = 25π rad/s

(a) waveform may be shifted as follows to obtain a more symmetrical waveform

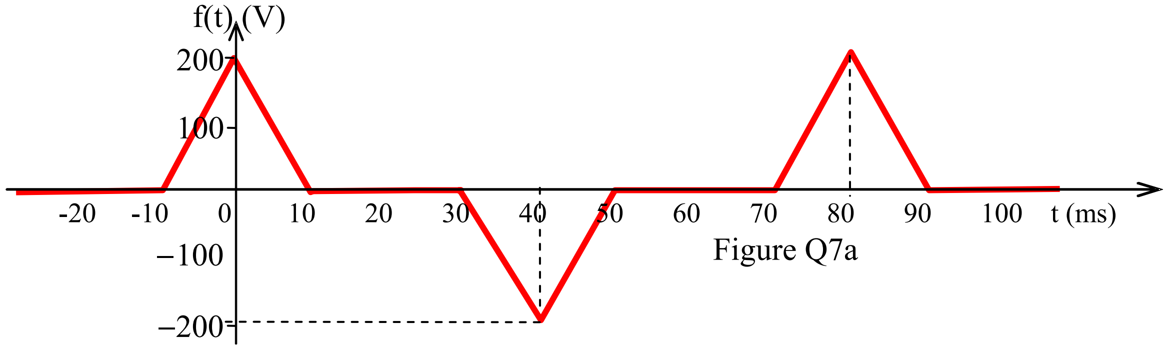


Figure Q7a

where e(t) = f(t – 0.01) + 100

f(t) = $A_0/2 + \sum A_n \cos n\omega t + B_n \sin n\omega t$

function f(t) has mean value = 0 → $A_0/2 = 0$

f(t) is even → $B_n = 0$ for all n

f(t) has half-wave symmetry → even harmonics = 0

$$\therefore A_n = 4 \times \frac{2}{T} \int_0^{0.02} f(t).\cos n\omega t.dt = \frac{8}{0.08}\left[\int_0^{0.01} (200 - 20000t).\cos n25\pi\, t.dt + \int_{0.01}^{0.02} 0.\cos n\omega\, t.dt\right]$$

EE 201 - THEORY OF ELECTRICITY – Short Answers

i.e. $A_n = 100 \times \left[(200 - 20000t).\dfrac{\sin n25\pi\, t}{n25\pi}\Bigg|_0^{0.01} + \int_0^{0.01} 20000.\dfrac{\sin n25\pi\, t}{n25\pi}.dt \right]$

$= 100\times[0+ (32/n^2\pi^2).(1 – \cos 0.25n\pi)]$

$A_1 = 100\times[(32/\pi^2).(1 – \cos 0.25\pi)] = 94.96$ V

$A_3 = 100\times[(32/9\pi^2).(1 – \cos 0.75\pi)] = 61.5$ V

$A_5 = ...$

$\therefore$ f(t) = 94.96 cos 25πt + 61.5 cos 75πt + ... **5 marks**

and e(t) = f(t – 0.01) +100 = 100+94.96 cos (25πt – 0.25π) + 61.5 cos (75πt – 0.75π) + ...

(b) mean value = 100 V

average value = (200×20+100×20+50×5+50×10+50×5+100×20)/80 = 112.5 V **2 marks**

rms value $= \sqrt{100^2 + \dfrac{94.96^2}{2} + \dfrac{61.5^2}{2} + ...}$ = 128 V (limited accuracy due to low terms)

form factor = 128/112.5 = 1.14

(c) $I_n = E_n/(jn25\pi\times0.2 + 1/jn25\pi\times10\times10^{-6})$

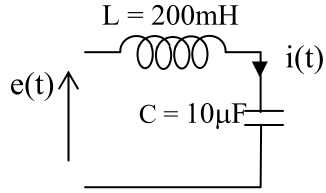


Figure Q7b

$$I_n = \frac{jn25\pi}{10^5 - 125n^2\pi^2} E_n$$

there will be no d.c. current flow due to the capacitance

$$I_1 = \frac{j25\pi}{10^5 - 125\pi^2} E_1 = \frac{25\pi\angle 90^0}{10^5 - 125\pi^2} E_1 = 0.000795\angle 90^0\, E_1$$ **3 marks**

$$I_3 = \frac{j75\pi}{10^5 - 1125\pi^2} E_3 = 0.00265\angle 90^0\, E_3$$

$\therefore$ i(t) = 0.075 cos (25πt – 0.25π) + 0.163 cos (75πt – 0.75π) + ...

(d) Laplace transform of the unit step L[h(t)] = $\int_0^\infty 1.e^{-st}dt = \dfrac{e^{-st}}{-s}\Bigg|_0^\infty = \dfrac{1}{s}$,

and for unit ramp r(t) = $\int_0^\infty t.e^{-st}dt = t.\dfrac{e^{-st}}{-s}\Bigg|_0^\infty - \int_0^\infty \dfrac{e^{-st}}{-s}.dt = -\dfrac{e^{-st}}{(-s)^2}\Bigg|_0^\infty = \dfrac{1}{s^2}$ **1 marks**

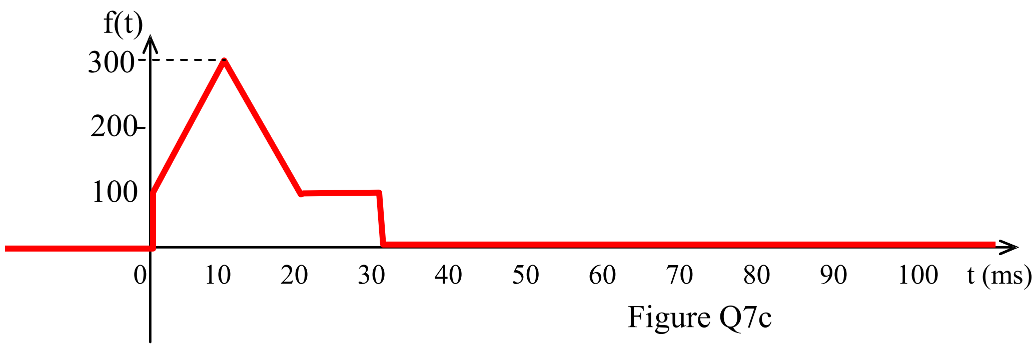


Figure Q7c

(e) given waveform can be split into ramps and steps as follows

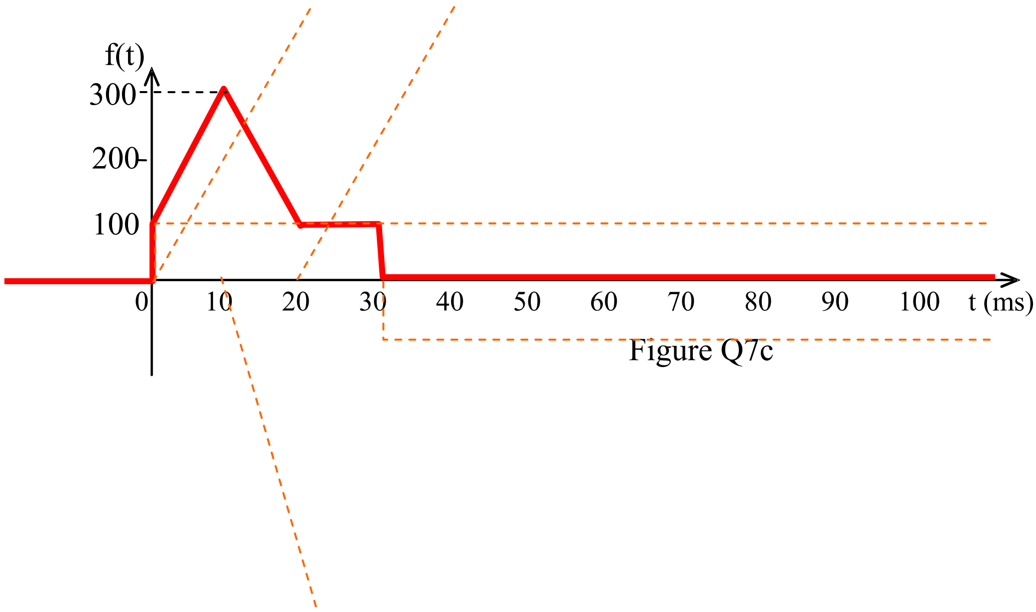


Figure Q7c

i.e. f(t) = 100 h(t) + 20000 r(t) – 40000 r(t–0.01) + 20000 r(t–0.02) – 100 h(t–0.03)

$$F(s) = \frac{100}{s} + \frac{20000}{s^2} - \frac{40000}{s^2}e^{-0.01s} + \frac{20000}{s^2}e^{-0.02s} - \frac{100}{s}e^{-0.03s}$$

3 marks