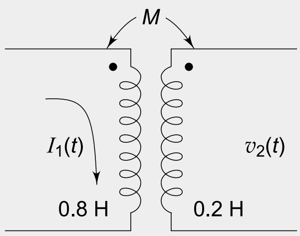
PAPER 3

1. (a) State the voltage current relationships for (i) resistance (ii) inductance and (iii) capacitance.

Solution Refer Sections 1.5, 1.6 and 1.7.

(b) Two coupled coils with self inductances L_1=0.8H and L_2=0.2H have a coupling coefficient of 0.6 has 500 turns. If the current in coil 1 is $I_1(t)$ = 10 sin 200t; determine the voltage at coil 2 and the maximum flux set up by the coil 1.

Solution



$$M = K\sqrt{L_1 L_2}$$
$$= 0.6\sqrt{0.8 \times 0.2}$$
$$= 240 \text{ mH}$$

The voltage across the coil 2 $v_2(t) = \pm M \dfrac{di_1(t)}{dt}$

$$v_2(t) = \frac{d}{dt}(10 \sin 200t)$$
$$v_2(t) = 2000 \text{C is } 200t \text{ volts}$$

(c) A torroid is made of steel rod of 2 cm diameter. The mean radius of torroid is 20 cm relative permeability of steel is 2000. Compute the current required to produce 1 m web of flux and 1000 turns in the torroid.

Solution Length of the flux path = $\pi D = \pi \times 20$ = 62.83 cm = 0.6283 m

Area of flux path = $\dfrac{\pi}{4} d^2 = \dfrac{\pi}{4}(2)^2 = 3.141 \text{ cm}^2$

Magnetic field intensity $H = \dfrac{B}{\mu_o \mu_r}$

$$B = \frac{\phi}{\text{Area}} = \frac{10^{-3}}{3.141 \times 10^{-4}} 3.1 \text{web / m}^2$$
$$H = \frac{3.1}{4\pi \times 10^{-7} \times 2000} = 1233.45 \text{ AT / m}$$
$$mmf = H \times l = 1233.45 \times 0.6283$$
$$= 775 \text{ A.T.}$$

$$\text{Exciting current} = \frac{mmf}{T}$$

$$= \frac{775}{1000} = 0.775 \text{ A}$$

2. (a) If $I_1 = 10\underline{|0°}$, $I_2 = 20\underline{|60°}$ and $I_3 = 12\underline{|-30°}$ find $I_1 + I_2 + I_3$.

Solution $\quad \mathrm{I}_1 + \mathrm{I}_2 + \mathrm{I}_3 = 10\underline{|0°} + 20\underline{|60°} + 12\underline{|-30°}$

$$= 30.392 + j11.32$$

$$= 32.432\ \underline{|20.429}$$

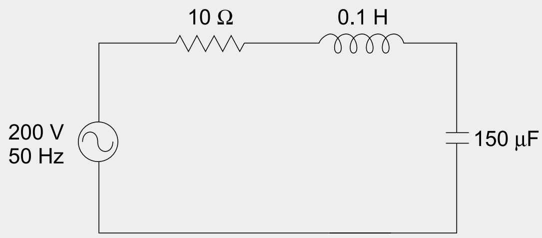
(b) Prove that the form factor for a sinusoidal current wave form is 1.11.

Solution Refer Section 4.4.7.

3. (a) Derive an expression for resonance frequency of a series R-L-C circuit.

Solution Refer Section 8.1.

(a) A coil of resistance 10*l* and an inductance of 0.1 H is connected in series with a capacitor of capacitance 150 μF a cross at 200V, 50Hz supply. Calculate (i) Impedance (ii) Current (iii) Power and power factor of the circuit



Solution (i) Total impedance

$$Z = R + j\omega L - \frac{j}{\omega c}$$

$$= 10 + j31.45 - j21.22$$

$$= 10 + j10.194$$

$$= 14.279\ \underline{|45.55}$$

(ii) Current $I = \dfrac{V}{Z}$

$$= \frac{200\underline{|0°}}{14.279\underline{|45.55°}}$$

$$= 14\underline{|-45.55°}$$

(iii) Power factor $= \cos(45.55^{o})$

$$= 0.7 \text{ lagging}$$

Real power $= VI \cos \phi$

$= 200 \times 14 \times 0.7$

$= 1.9$ kW

Reactive power $= VI \sin \phi$

$= 200 \times 14 \times \sin(-45.55)$

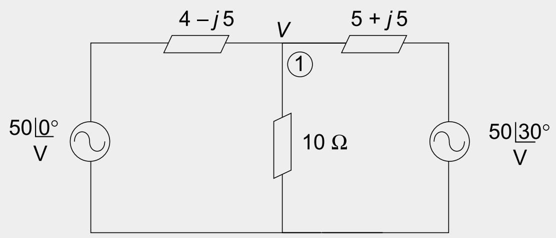
$= -1.998$ KVAR

"–1" Sign indicates that it absorbs the reactive power.

4. (a) Define cut set and tie set

Solution Refer Sections 2.7 and 2.8.

(b) Determine the current in the 10 Ω resistor in the circuit shown in the figure below.



Solution Apply nodal analysis at point (1), we get

$$\frac{V - 50\angle 0^\circ}{4 - j5} + \frac{V}{10} + \frac{V - 50\angle 30^\circ}{5 + j5} = 0$$

$$V\left[\frac{1}{4-j5} + \frac{1}{10} + \frac{1}{5+j5}\right] = \frac{50\angle 0^\circ}{4-j5} + \frac{50\angle 30^\circ}{5+j5}$$

$V\,[0.297 + j0.0219] = 11.708 + j4.267$

$V\,[0.298\angle 4.219^\circ] = 12.46\angle 20.02^\circ$

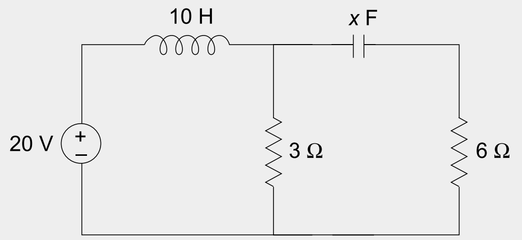
$\Rightarrow V = 41.812\ \angle 15.801^\circ$

Current through the 10 Ω resistor $I_{10} = \dfrac{V}{R}$

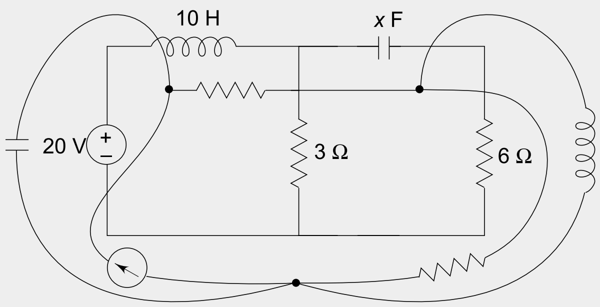
$= \dfrac{41.812\angle 15.801^\circ}{10}$

$= 4.1812\ \angle 15.80^\circ$ Amp

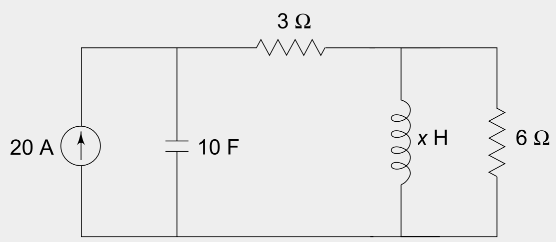
5. Draw the dual network for the given network as in the following figure.



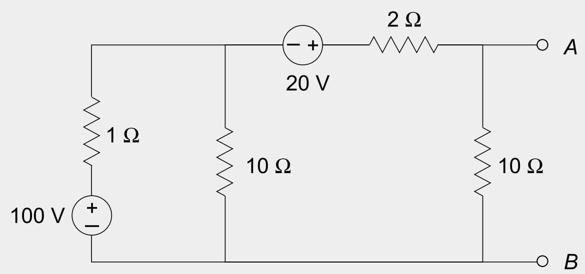
Solution



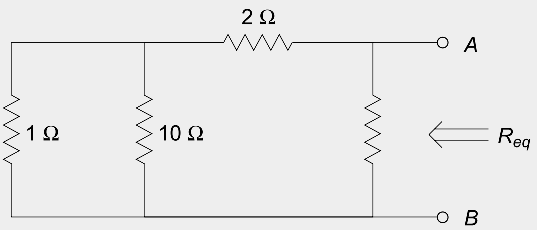
Dual network



6. (a) Obtain the Norton's equivalent circuit at the terminals *A*, *B* for the following figure.



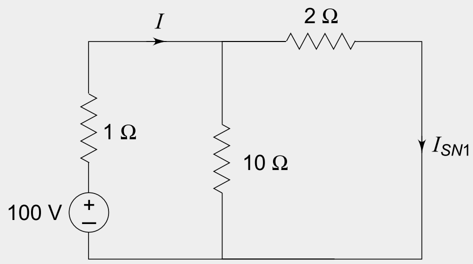
For finding the Nortons resistance, replace the voltage sources by the short circuit.



$$R_{eq} = \{[(1 \,||\, 10)+2] \,||\, 10\}$$
$$= 2.253\ \Omega$$

For finding the I_N short the terminals A and B and find current I_N. Apply superposition

(i) with 100 V source

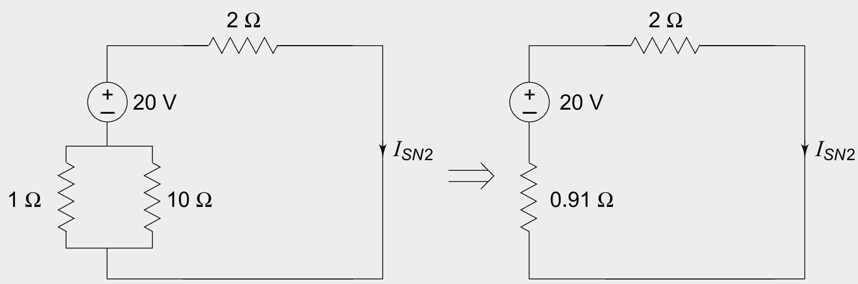


$$Z = [(2\|10)+1] = 2.67$$

Total current $I = \dfrac{100}{Z}$

$$= \frac{100}{2.67} = 37.45 \text{ A}$$

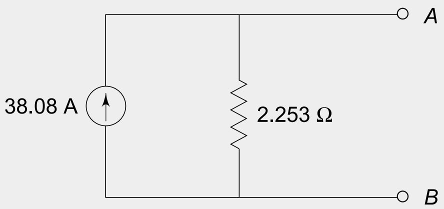
(ii) With 20 V source



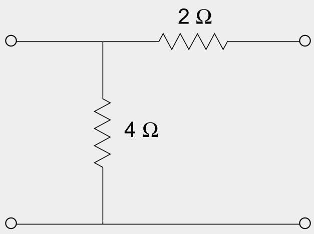
$$I_{SN2} = \frac{20}{2.91} = 6.872 \text{ A}$$

$$\therefore I_{SN} = I_{SN_1} + I_{SN_2}$$
$$= 31.21 + 6.872$$
$$= 38.08 \text{ A}$$

$\therefore$ Nortons equivalent circuit is given by



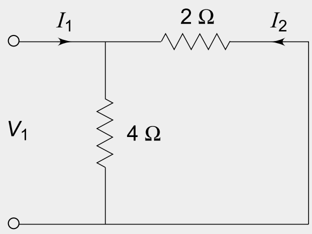
(b)



For the 2 port network, find *h*-parameters.

Solution We know that

$$V_1 = h_{11}I_1 + h_{12}V_2$$
$$I_2 = h_{21}I_1 + h_{22}V_2$$



$$h_{11} = \left.\frac{V_1}{I_1}\right|_{V_2=0}$$

$$h_{21} = \left.\frac{I_2}{I_1}\right|_{V_2=0}$$

$$\therefore \quad h_{11} = \frac{1.33I_1}{I_1} = 1.33\Omega$$

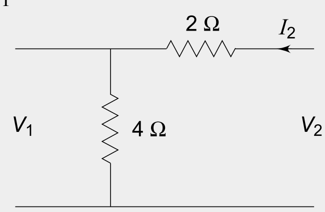
$$h_{21} = -\frac{4}{6}\frac{I_1}{I_1} = -0.66$$

$$V_1 = (2\,||\,4)I_1$$
$$= 1.33\ \mathrm{I}_1$$
$$I_2 = -I_1 \times \frac{4}{6}$$

$$h_{12} = \left.\frac{V_1}{V_2}\right|_{I_1=0}$$

$$h_{12} = \left.\frac{I_{21}}{V_2}\right|_{I_1=0}$$

If $I_1 = 0$

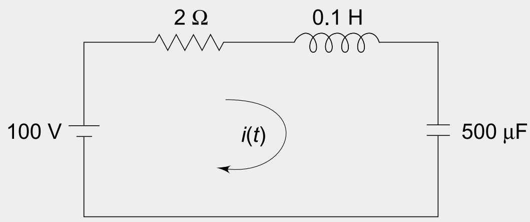


$$h_{22} = \frac{I_2}{6I_2}$$
$$= 0.166v$$

$$V_1 = 4I_2$$

$$h_{12} = \frac{4I_2}{6I_2} \qquad V_2 = 6I_2$$
$$= 0.66$$

7. A series RLC circuit with $R = 5\ \Omega$, $L = 0.1$H and $C = 500\ \mu$F has a D.C. voltage of 100V applied at $t = 0$ through a switch. Find the resulting current transient.



Solution $\quad 5i(t) + 0.1\ \mathrm{L}\ \dfrac{di(t)}{dt} + \dfrac{1}{500 \times 10^{-6}} \int i(t)dt = 100$

$$\frac{d^2i}{dt^2} + 50\frac{di}{dt} + 2000 = 0$$

$D^2 + 50D + 2000 = 0$

$D = -25 \pm j37.08$

$\therefore i(t) = e^{-25t}\,[K_1 \cos 37.08t + K_2 \sin 37.08t]$ (1)

1^{st} initial condition is that current through the inductor cannot change instantaneously.

Also voltage drop across capacitor cannot change instantaneously

Hence at $t = 0^+$

$$\frac{di}{dt}(0^+) = \frac{V_o}{L} = \frac{100}{0.1} = 1000$$

Substituting initial conditions $i(0^+) = 0$

$\therefore \qquad 0 = K_3$

On differentiating equation (1), we get

$$\frac{di}{dt} = e^{-25t}\left[-37.08K_1 \sin 37.08t + 37.08K_2 \cos 37.08\right]$$
$$-25e^{-25t}(K_1 \cos 37.08t + K_2 \sin 37.08)$$
$$= e^{-25t}\left[\sin 37.08t\,(-37.08K_1 - 25K_2) + \cos 37.08t(37.08K_2 - 25K_1)\right]$$

$$\frac{di}{dt}(0^+) = 37.08K_2 - 25K_1$$

$$\Rightarrow K_2 = \frac{1000}{37.08} = 26.96$$

$\therefore\ i(t) = e^{-25t}\,(26.96 \sin 37.08t)$

8. (a) Explain Dot convention.

Solution Refer Section 9.4.

8. (b) Explain briefly about the locus diagrams.

Solution Refer Section 8.6.