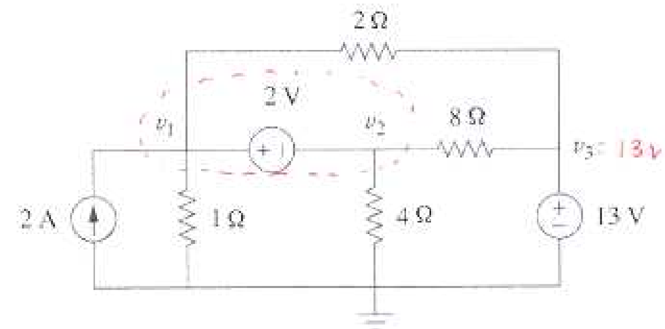
Lesson 37: Final Exam Review

Example Problem 1

Calculate the node voltages in the circuit below.



KVL $\quad v_1 = v_2 + 2$

$$\underbrace{\frac{v_1-13}{2} + \frac{v_2-13}{8} + \frac{v_2}{4} + v_1 - 2 = 0}$$

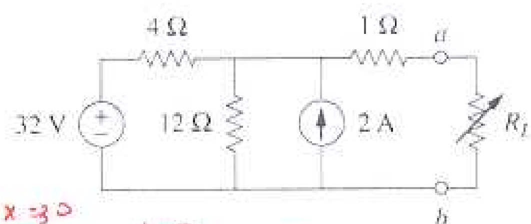
$$12v_1 + 3v_2 = 81$$

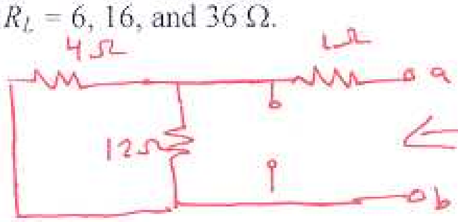
$$v_1 - v_2 = 2$$

$$\begin{bmatrix} 12 & 3 \\ 1 & -1 \end{bmatrix}\begin{bmatrix} v_1 \\ v_2 \end{bmatrix} = \begin{bmatrix} 81 \\ 2 \end{bmatrix} \Rightarrow \boxed{\begin{aligned} v_1 &= 5.8\text{ V} \\ v_2 &= 3.8\text{ V} \\ v_3 &= 13\text{ V} \end{aligned}}$$

Example Problem 2

Find the Thévenin equivalent circuit to the left of terminals *a*-*b*. Then find the current through R_L = 6, 16, and 36 Ω.

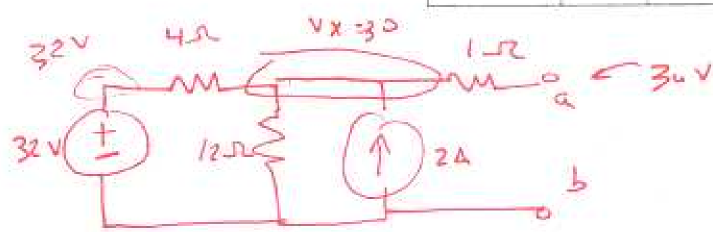




$$R_{th} = 4 \| 12 + 1$$

$$= 3 + 1$$

$$R_{th} = 4\ \Omega$$



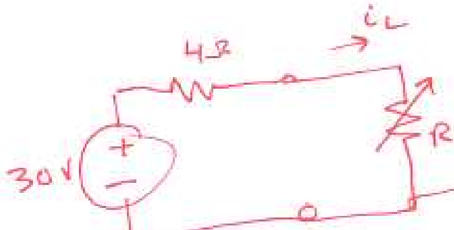
$$\frac{v_x-32}{4} + \frac{v_x}{12} - 2 = 0$$

$$3v_x - 96 + v_x - 24 = 0$$

$$4v_x = 120$$

$$v_x = 30\text{ V}$$

$$V_{th} = 30\text{ V}$$

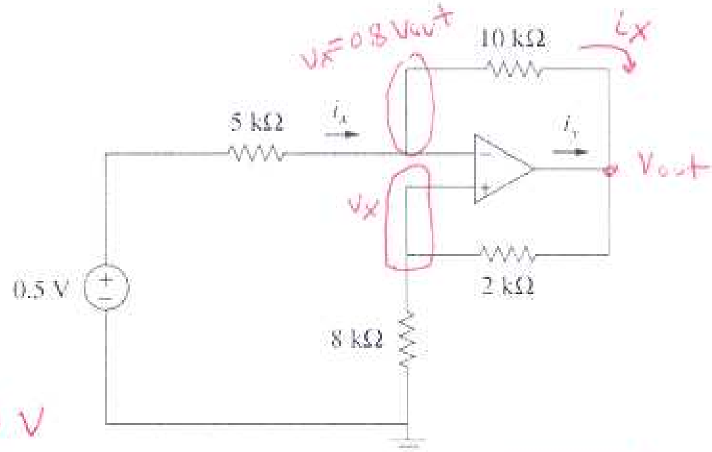


$$i_L = \frac{30}{4+R_L}$$

R_L	i_L
6	3 A
16	1.5 A
36	0.75 A

Example Problem 3

Determine i_x and i_y below.



① label output voltage V_{out}

② $V_y = \frac{8k}{8k+2k} \cdot V_{out} = 0.8\ V_{out}$

③ KCL at inverting input

$$\frac{0.8\ V_{out} - 0.5}{5k} + \frac{0.8\ V_{out} - V_{out}}{10k} = 0$$

$$\Rightarrow V_{out} = 5/7\ V = 0.714\ V$$

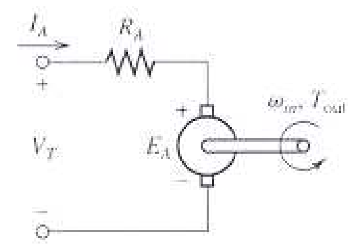
④ $i_x = \frac{0.5 - 0.8\ V_{out}}{5k} = \frac{0.5 - 0.8(5/7)}{5k} = -0.0143\ mA = \boxed{-14.3\mu A}$

⑤ KCL at V_{out} to find i_y

$$i_x + i_y = \frac{V_{out}}{2k+8k} \Rightarrow i_y = \frac{0.714\,V}{10k} + 0.0143 = \boxed{85.7\mu A}$$

Example Problem 4

A 120-V permanent magnet DC motor tested under two conditions: loaded and unloaded. Without a load the speed of the motor ω_m is 160 rad/s and I_A is 1 A. With a load, the speed of the motor ω_m is 148.6 rad/s and I_A is 2 A. Solve for R_a, K_v and T_{loss}.



$$V_T = I_A R_A + K_v \omega$$

case 1: $120 = (1) R_A + K_v \cdot 160$

case 2: $120 = 2 R_A + K_v \cdot 148.6$

$$\begin{bmatrix} 1 & 160 \\ 2 & 148.6 \end{bmatrix} \begin{bmatrix} R_A \\ K_v \end{bmatrix} = \begin{bmatrix} 120 \\ 120 \end{bmatrix} \Rightarrow \boxed{\begin{matrix} R_A = 7.98\ \Omega \\ K_v = 0.7\ V \cdot s \end{matrix}}$$

Find T_{loss} $\quad \cancel{T_{out}}^{0} = T_{dev} - T_{loss}$ (case 1: $T_{out} = \emptyset$, unloaded)

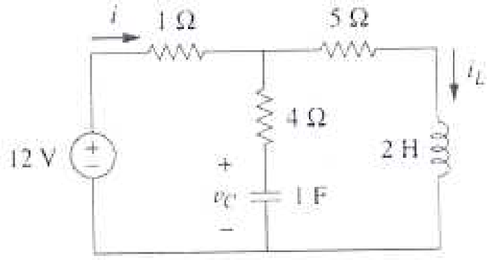
$$\Rightarrow T_{dev} = T_{loss} = K_v I_A$$

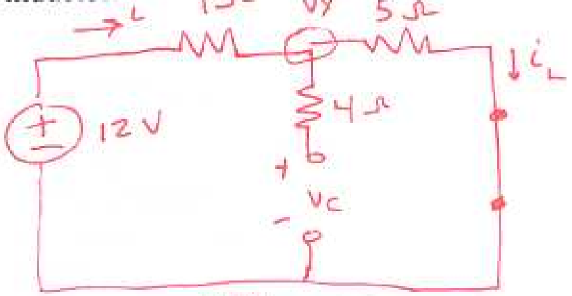
$$= (0.7)(1A)$$

$$\boxed{= 0.7\ N \cdot m}$$

Example Problem 5

Under dc conditions find i, v_C, and i_L. Also, determine the energy stored in the capacitor and inductor.





$i = \frac{12\,V}{1+5} = \frac{12}{6} = 2\,A$

$i_L = 2\,A$

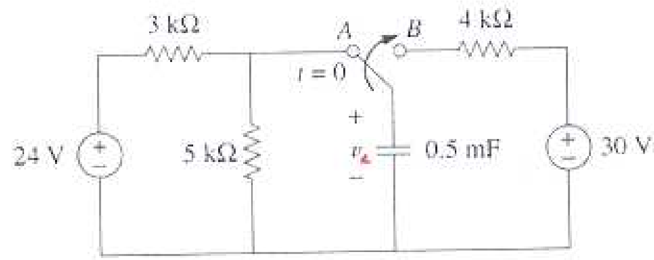
$v_C = v_x = 12 \cdot \frac{5}{5+1} = 10\,V$

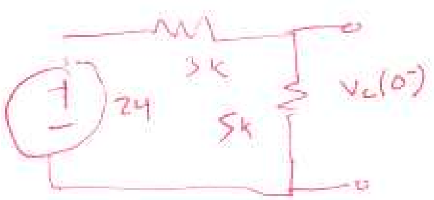
$W_C = \frac{1}{2} C V^2$
$= \frac{1}{2}(1F)(10)^2$
$= 50\,J$

$W_L = \frac{1}{2} L i^2$
$= \frac{1}{2} \cdot 2 \cdot 2^2$
$= 4\,J$

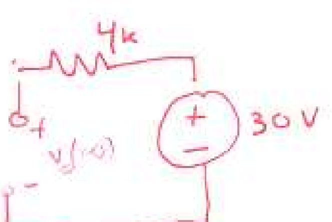
Example Problem 6

The switch in the circuit below has been in position A for a long time. At $t = 0$, the switch moves to B. Determine $v(t)$ for $t \geq 0$ and calculate its value at $t = 2$ and 4 sec.





$v_C(0) = 24 \cdot \frac{5}{5+3} = 15\,V$



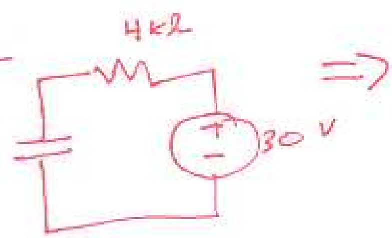
$v_C(\infty) = 30\,V$

$\tau = RC$
$= (4000)(.0005\,F)$
$= 2\,sec$

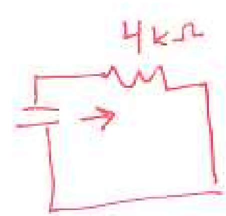
$v_C(t) = v(\infty) + [v(0^+) - v(\infty)]e^{-t/\tau}$
$= 30 + [15 - 30]e^{-t/2}$

$\boxed{= 30 - 15e^{-t/2}}$

$\tau = RC$



$\Rightarrow$

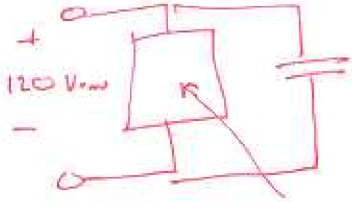


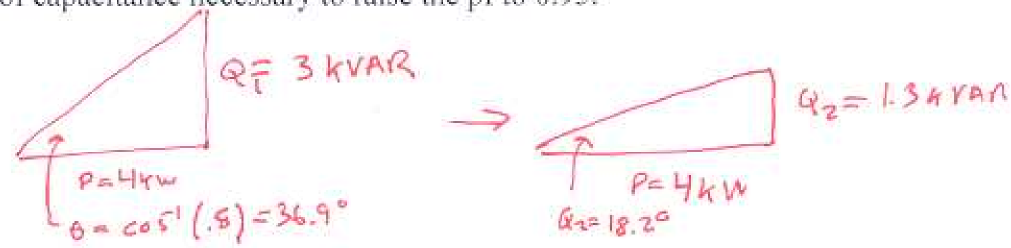
$R = 4k\Omega$

$\boxed{\begin{array}{l} v_C(2) = 24.48\,V \\ v_C(4) = 27.97\,V \end{array}}$

Example Problem 7

When connected to a 120-Vrms, 60-Hz power line, a load absorbs 4 kW at a lagging power factor of 0.8. Find the value of capacitance necessary to raise the pf to 0.95.



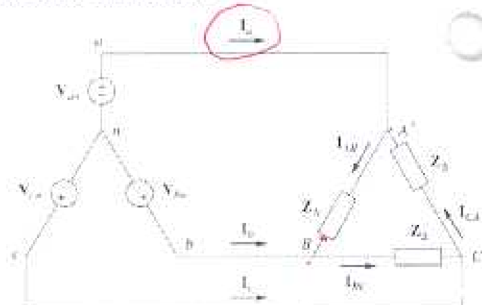


$$Q_c = Q_2 - Q_1$$
$$= -1.7 \text{ kVAR}$$

$$C = \frac{Q_c}{\omega V^2} = \frac{1700}{377 \cdot 120^2} = \boxed{313 \mu F}$$

Example Problem 8

A balanced *abc*-sequence Y-connected source with $V_{an} = 1000\angle 10°$ V is connected to a Δ-connected balanced load $(8 + j4)\ \Omega$ per phase. Calculate the phase and line currents.



$V_{an} = 1000\angle 10°$

$V_{ab} = 1730\angle 40°$ V

$$I_{AB} = \frac{V_{ab}}{Z_\Delta} = \frac{1730\angle 40°}{8 + j4} = 193.4\angle 13.4° \text{ A}$$

$$I_A = \sqrt{3}\ I_{AB}\ \angle -30°$$
$$= \sqrt{3}\left(193.4\angle(13.4 - 30)\right)$$
$$= 335\angle -16.6° \text{ A}$$

$I_{AB} = 193.4\angle 13.4°$ A

$I_{BC} = 193.4\angle -106.7°$ A

$I_{CA} = 193.4\angle 133.4°$ A

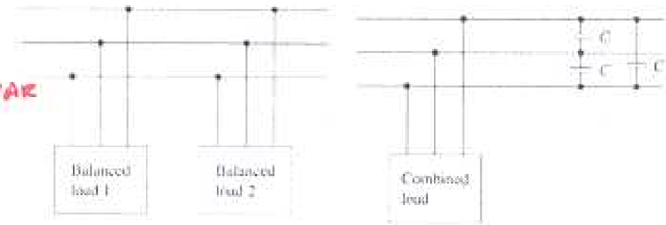
$I_A = 335\angle -16.6°$ A

$I_B = 335\angle -136.6°$ A

$I_C = 335\angle 103.4°$ A

Example Problem 9

Two balance loads are connected to a 240-kV rms, 60-Hz line. Load 1 draws 30 kW (pf=0.6 lagging) while load 2 draws 45 kVAR (pf=0.8 lagging). Assuming the *abc* sequence determine the (a) the complex, real and reactive powers absorbed by the load, (b) the line currents, and (c) the kVAR rating of the 3 capacitors D-connected in parallel that will raise the pf to 0.9 lagging and the capacitance of each capacitor.



load 1: per phase ($P_p = 10$ kW, pf = 0.6 lag)

$\theta = 53.1°$ $\quad Q_1 = 13.3$ kVAR $\quad P_1 = 10$ kW

load 2: per phase ($Q_p = 15$ kVAR, pf = 0.8)

15 kVAR $= Q_2$ $\quad P_2 = 20$ kW

a) combined (per phase) $P_{p} = 10 + 20 = 30$ kW

$Q_{1p} = 13.3 + 15 = 28.3$ kVAR

$\Rightarrow$ total: $S = 123.8$ kVA $\quad Q_{3p} = 85$ kVAR $\quad \theta = 43.4°$ $\quad P_{3p} = 90$ kW

b) line currents $\quad S = \sqrt{3}\, V_L I_L$

$$I_L = \frac{123.8\text{ kVA}}{\sqrt{3} \cdot 240\text{ kV}} = \boxed{0.298\text{ A}}$$

c) to change to pf = 0.9 $\rightarrow$ Q

$\theta = \cos^{-1}(0.9) = 25.84$

$Q = 14.5$ kVAR $\quad 30$ kW

$Q_C = 28.3 - 14.5 = \boxed{13.9\text{ kVAR}}$

$$C = \frac{Q_c}{\omega V^2} = \frac{13800}{377\,(240\times10^3)^2} = \boxed{636\text{ pF}}$$

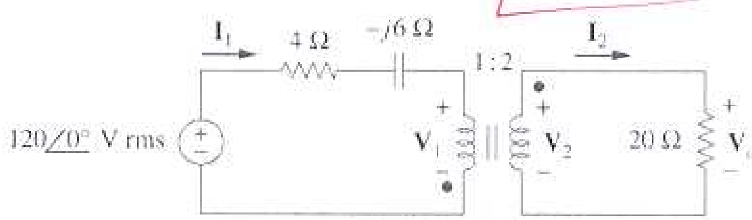
Example Problem 10

For the ideal transformer below find

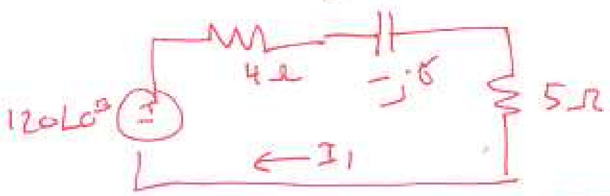
a. the source current I_1

b. the output voltage V_o

c. the complex power supplied by the source



$$Z_R = \frac{1}{n^2} \cdot Z_L = \frac{1}{2^2} \cdot 20 = 5\,\Omega$$



$$\vec{S} = \vec{V} \cdot \vec{I}_1^{\,*}$$

$= (120)(11.1\angle -33.7)$

$\boxed{= 1331 \angle 33.7°\text{ VA}}$

$$I_1 = \frac{120\angle 0°}{9 - j6} = \boxed{11.1\angle 33.7°\text{ A}}$$

$$I_2 = \frac{1}{n} \cdot I_1 = -\frac{1}{2} \cdot 11.1\angle 33.7$$

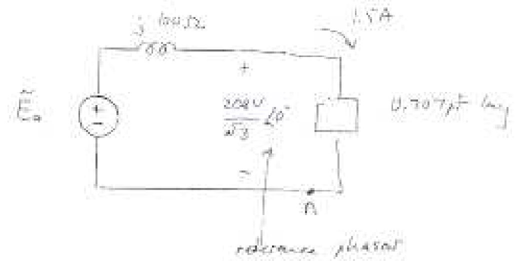
$= 5.55\angle{-146}°$ A

$$\vec{V}_o = \vec{I}_2 \cdot 20\,\Omega = \boxed{111\angle -146°\text{ V}}$$

Example Problem 11

A 208-V_{rms} (line), 60 Hz, Y-connected generator has $X_s = 100\ \Omega$, $r_s = 0\ \Omega$. At rated terminal voltage, the machine delivers 1.5-A_{rms} (line) to a 0.707 pf lagging load.

a. Determine the machine current.
b. Determine the excitation (or generator) voltage E_a.
c. Determine the power (torque) angle δ.
d. If the generator has 4 poles, what is the speed of the prime mover.
e. Determine the developed torque.
f. Suppose the load current increases to 3-A_{rms} at a 0.707 lagging pf. If we have the same terminal voltages, how must the field current change?



a) load is 0.707 pf lagging → pf = cos θ ⇒ θ = 45°

$\boxed{I_A = 1.5\angle -45°\ A}$

b) $\tilde{E}_a = I_A(\cancel{R_s}^{0} + jX_s) + \tilde{V}_{AS}$

$= 1.5\angle -45°(j100) + 120\angle 0°$

$\boxed{= 249.8\angle 25.1°\ V}$

c) $\boxed{\delta = 25.1°}$

d) $N_m = \frac{120 f_e}{P} = \frac{120(60)}{4} = \boxed{1800\ rpm}$

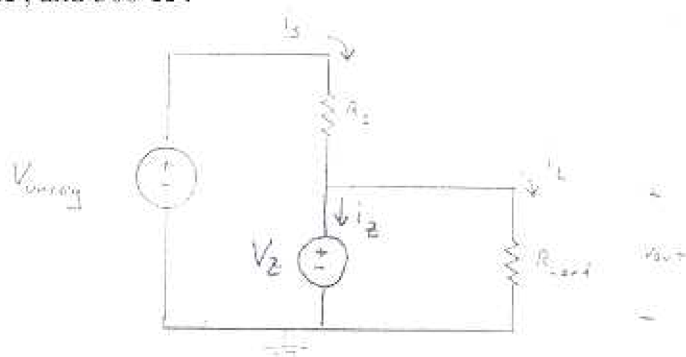
e) $T_{dev} = \frac{1}{2}\frac{3 V_s E_a}{\omega_e X_s}\sin\delta = \frac{4}{2}\cdot\frac{3(120)(249.8)}{(377)(100)}\sin(25.1) = \boxed{2.027\ N\cdot m}$

f) see lecture 30 notes $(I_{F2} = I_{F1}\cdot 1.58)$

Example Problem 12

Suppose you choose a 0.5 W, 9 V zener diode for a load application where 300-Ω < R_{load} < ∞. Determine the range of V_{unreg} for R_s = 20-Ω, 100-Ω, and 500-Ω.

$\cancel{i_{Zmax} = \frac{0.8(0.5\,W)}{9\,V}}$



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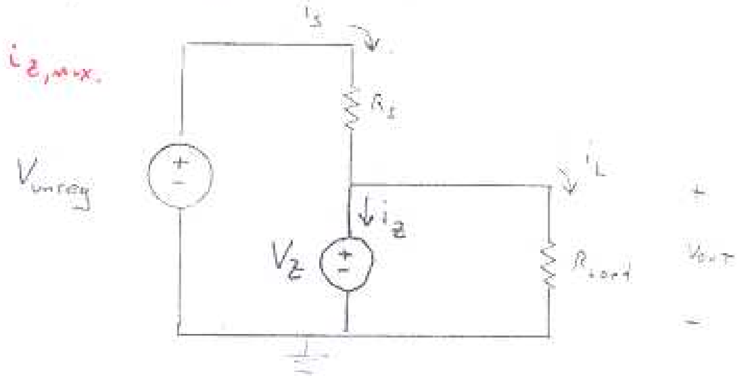

Step 1: Determine target values for $i_{z,min}$ & $i_{z,max}$.

$$i_{z,max} = 0.8 \frac{P_z}{V_z} = 0.8 \frac{0.5\,W}{9\,V} = 44.4\,mA$$

$$i_{z,min} = \frac{i_{z,max}}{50} = 0.89\,mA$$

Step 2: For $R_s = 20\,\Omega$

unknown

$$i_{z,min} = 0.89\,mA = \frac{V_{unreg,min} - V_z}{R_s} - \frac{V_z}{R_{load,min}} \leftarrow 300\,\Omega$$

$$i_{z,max} = 44.4\,mA = \frac{V_{unreg,max} - V_z}{R_s} - \frac{V_z}{R_{load,max}} \leftarrow \infty$$

$V_{unreg,min} = 9.62\,V$

$V_{unreg,max} = 9.89\,V$

Step 2b:

Repeat for $R_s = 100$ & $R_s = 500\,\Omega$

$R_s = 100\,\Omega$: $V_{unreg,min} = 12.09\,V$, $V_{unreg,max} = 13.44\,V$

$R_s = 500\,\Omega$: $V_{unreg,min} = 24.45\,V$, $V_{unreg,max} = 31.2\,V$

Step 3: Max power dissipated by R_s?

$$P_{R_s,max} = \frac{(V_{unreg,max} - V_z)^2}{R_s}$$

	20 Ω	100 Ω	500 Ω
$P_{R_s,max}$ =	0.04 W	0.197 W	0.985 W

- If we need a smaller ripple for V_{unreg}, need to use larger C.

- Higher ripple causes higher voltage levels and more power dissipation by R_s.