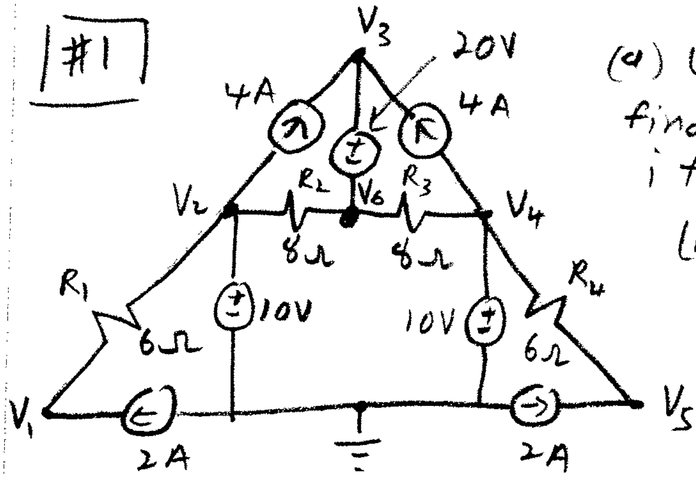
ENGG 325 Final Exam Solns Dec 2008

#1

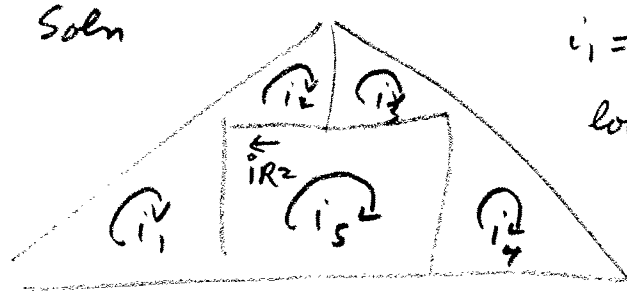


(a) Using the mesh current method find the power for R_2, stating if absorbed or supplied.

(b) Using the node voltage method find all node voltages.

(c) Use your results from part (b) to verify your answer for part (a).

Soln



$i_1 = 2A \quad i_2 = 4A \quad i_3 = -4A \quad i_4 = -2A$

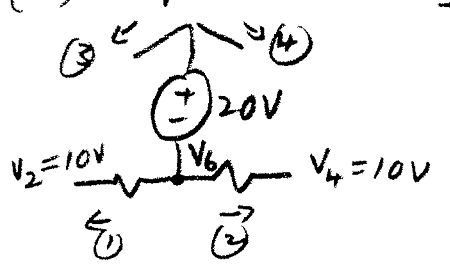
loops: $-10 + 8(i_5 - 4) + 8(i_5 + 4) + 10 = 0$

$\Rightarrow i_5 = 0$

$\therefore i_{R2} = i_2 - i_5 = 4A$

$\therefore P = i^2 R = 4^2 \cdot 8 = \boxed{128W \text{ absorbed}}$

(b) supernode: $\frac{V_6 - 10}{8} + \frac{V_6 - 10}{8} + (-4A) + (-4A) = 0$



$\Rightarrow 2\left(\frac{V_6 - 10}{8}\right) = 8$

$\Rightarrow \boxed{V_6 = 32 + 10 = 42V}$

other nodes:

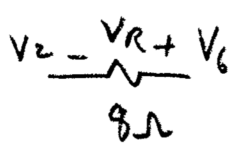
$\boxed{V_2 = 10V}$ $\boxed{V_4 = 10V}$ ← given

or you can find V_1 & V_5 by node eqns →

$V_1 = V_2 + 2A * 6 = 22V$ $\quad V_5 = 22V$

$\boxed{V_3 = V_6 + 20 = 62V}$ ← also called supernode constraint

(c)



$V_R = V_6 - V_2 = 32V$

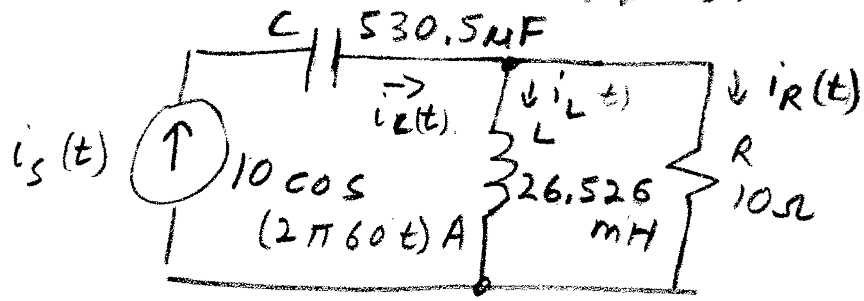
$P = V^2/R = 32^2/8 = 128W$ ✓ absorbed

There are other ways to find power in (a), (b) eg $P = Vi$

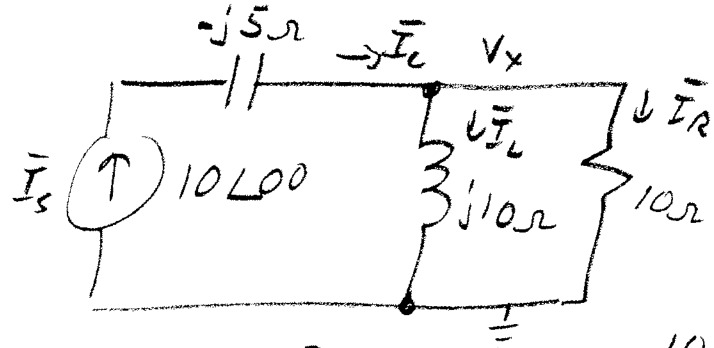
#2 Consider the AC circuit of Fig. P2.

(a) Find $i_c(t)$, $i_L(t)$, $i_R(t)$.

(b) Find the average power for each component including the current source. State if power is absorbed or supplied.



Soln



$\omega L = 2\pi 60 L$
$= 10\Omega$

$\frac{1}{\omega C} = 5\Omega$

$\bar{I}_c = \bar{I}_s$

current divider

$\bar{I}_L = \bar{I}_s \times \frac{R}{R+j\omega L} = 10\angle 0^\circ \times \frac{10}{10+j10} \leftarrow 45^\circ$

$= \frac{10}{\sqrt{2}} \angle -45^\circ$ A

$I_R = \bar{I}_s \times \frac{j\omega L}{R+j\omega L} = 10\angle 0^\circ \times \frac{10\angle 90^\circ}{10+j10} = \frac{10}{\sqrt{2}} \angle 90^\circ - 45^\circ$

$= \frac{10}{\sqrt{2}} \angle +45^\circ$

$\therefore$
$i_c(t) = 10 \cos \omega t$ A
$i_L = \frac{10}{\sqrt{2}} \cos(\omega t - 45^\circ)$ A
$i_R(t) = \frac{10}{\sqrt{2}} \cos(\omega t + 45^\circ)$ A

or by node method:

$-10 + \frac{V_x}{j10} + \frac{V_x}{10} \Rightarrow V_x = \frac{100}{\sqrt{2}} \angle -45^\circ$ etc.

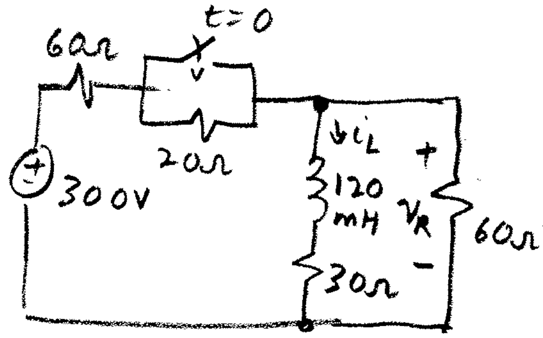
(b) C and L have zero average power.

R: $P = I_{RMS}^2 R = \left(\frac{7.07}{\sqrt{2}}\right)^2 \times 10 = 250W$ absorbed

$\therefore$ I_s supplies 250W on average.

#3

For the resistor-inductor circuit...



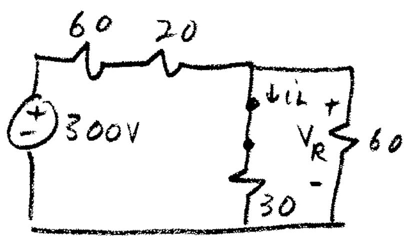
(a) Express $i_L(t)$ ... sketch

(b) " $V_R(t)$ ... sketch

(c) Find power for the inductor just before and after the switch is closed.

Soln: step1

At $t=0^-$



$P_L = vi = 0 \cdot 2A = \boxed{0W}$

$60 \| 30 = 20\Omega$

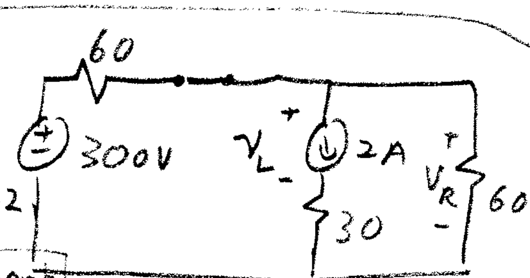
$\therefore V_R(0^-) = 300 \times \frac{20\Omega}{60+20+20}$

$V_R(0^-) = \boxed{60V}$

$i_L(0^-) = \frac{60V}{30\Omega} = \boxed{2A}$

step2

$t=0^+$



$P_L = V_L i_L$
$= (90-2\cdot 30)\cdot 2$
$= 30V \cdot 2A$
$= \boxed{60W \text{ absorb}}$

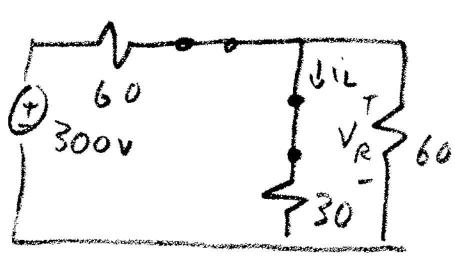
$\frac{V_R - 300}{60} + 2A + \frac{V_R}{60} = 0$

$\Rightarrow \boxed{V_R(0^+) = 90V}$

$\boxed{i_L(0^+) = 2A}$

step 3

$t=\infty$



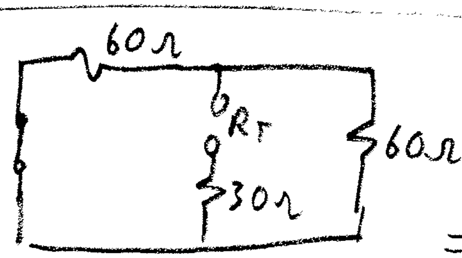
$60 \| 30 = 20\Omega$

$\Rightarrow V_R(\infty) = 300 \times \frac{20}{80} = \boxed{75V}$

$i_L(\infty) = \frac{75}{30} = \boxed{2.5A}$

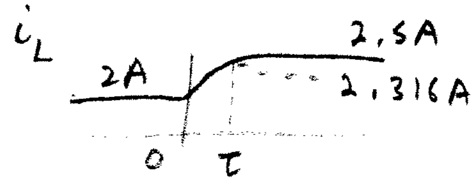
Step4

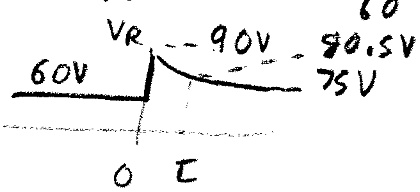
$R_T = R_{eq}$



$R_{eq} = R_T = 30 + 60\|60 = 60\Omega$

$\Rightarrow \frac{L}{R} = \tau = \frac{120mH}{60} = \boxed{2ms}$





$$\left.\begin{aligned} i_L(t) &= 2.5 + (2-2.5)e^{-t/\tau} \\ &= 2.5 - .5e^{-t/\tau} \end{aligned}\right\} \underline{t \geq 0}$$

$$\left.\begin{aligned} V_R(t) &= 75 + (90-75)e^{-t/\tau} \\ &= 75 + 15e^{-t/\tau} \end{aligned}\right\} \text{for } \underline{t \geq 0}$$

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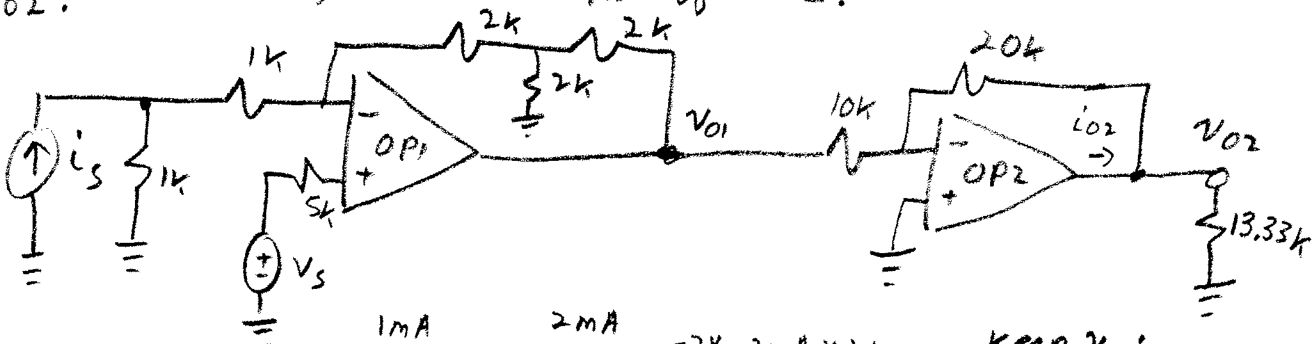
#4 a) For circuit... If $i_s = 2mA$ and $V_s = 1V$, use the principle of superposition to find V_{O2}.

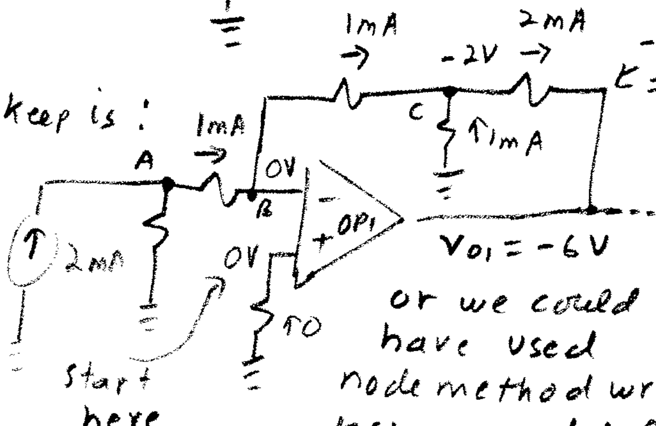
Hint one way to do this is to find i_{O2}.

b) If $i_s = 2mA$ and $V_s = 1V$, find the power output of OP2.

c) If $i_s = 2\cos(1000t)$ mA and $V_s = 1\cos(1000t)$ V, find the average power output of OP2.

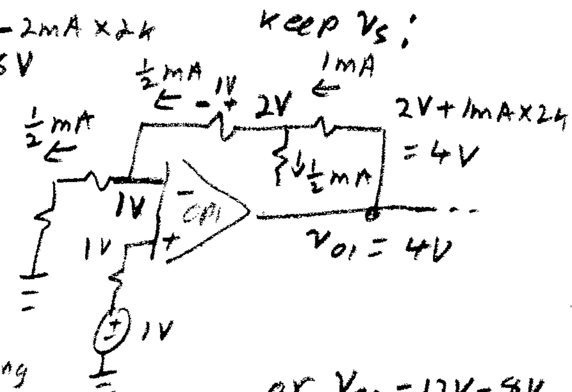


(a) keep i_s:



or we could have used node method writing KCL eqns at A, B, C.

keep V_s:



or $V_{O2} = 12V - 8V = 4V$

By superposition $V_{O1} = -6V + 4V = -2V$

But OP2 stage has gain $-\frac{20k}{10k} = -2 \Rightarrow V_{O2} = -2 \times -2 = \boxed{4V}$

(b) One way: $i_{O2} = \frac{V_{O2}}{20k} + \frac{V_{O2}}{13.3k} = \frac{4}{20k} + \frac{4}{13.3k} = 0.5mA$

$\Rightarrow P_{O2} = V_{O2}\, i_{O2} = 4V \times .5mA = 2mA$ absorbed by 20k and 13.33k

$\therefore$ OP2 is supplying $\boxed{2mW.}$

(c) From part (a) we can generalize:

$V_{O1} = -3 i_s + 4 V_s$ or $V_{O2} = 6 i_s - 8 V_s$

$\therefore V_{O2} = 6 \times 2\cos 1000t - 8 \times \cos 1000t = 4\cos(1000t)$ V

By similar process in (b): $i_{O2} = 0.5\cos(1000t)$ mA

P_{O2} avg $= V_{O2\,RMS} \times I_{O2\,rms} = \frac{4}{\sqrt{2}}V \times \frac{.5}{\sqrt{2}} mA = \boxed{1mW}$

There are othe ways to think about this.

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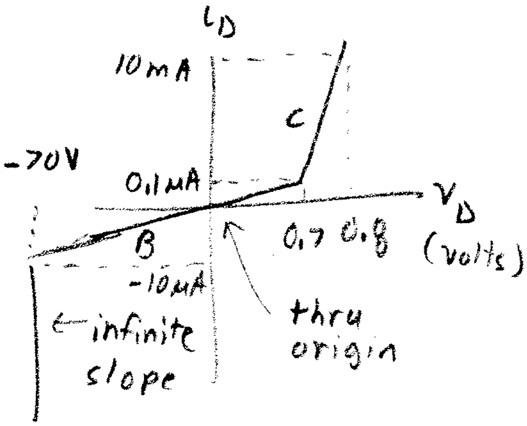
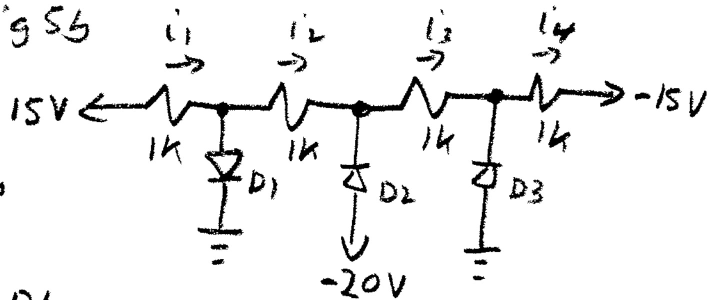
make any reasonable assumptions

#5 (a) Give the diode equivalent circuit corresponding to each line segment of Fig 5a

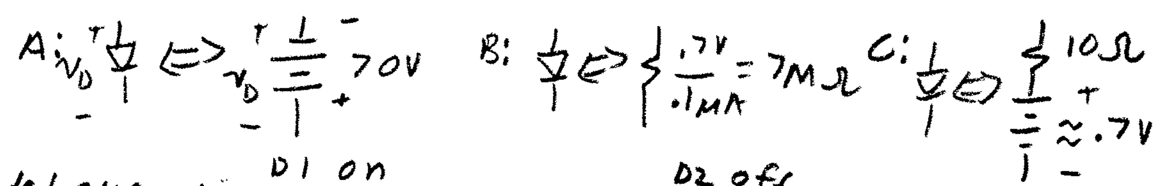
(b) For the circuit of Fig 5b, Assuming ideal diodes, find i_1, i_2, i_3, i_4, and find the power dissipated by diode D1.



(c) For the circuit of Fig 5b now assume the diodes are characterized by the i_D / V_D relationship of Fig 5a. Find ... i_1 i_2 i_3 i_4 ... power D1.

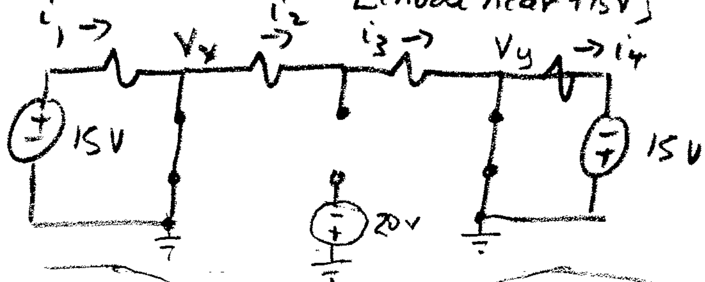


Soln



(b)

Educated guess: D1 on [anode near +15V] D2 off [looks reverse bias] D3 on [cathode near -15V]



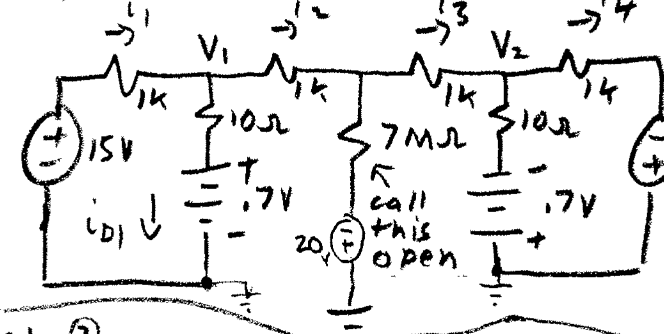
$V_x = V_y = 0V$

$i_1 = \frac{15V}{1k} = 15mA$ $\quad i_2 = i_3 = \frac{V_x - V_y}{2k} = 0$

$i_4 = \frac{0-(-15)}{1k} = 15mA$

$P_{D1} = vi = 0V * 15mA = 0$ watts

(c)



step ① node 1 $\frac{V_1 - 15}{1k} + \frac{V_1 - .7}{10} + \frac{V_1 - V_2}{2k} = 0$

$\Rightarrow V_2 = 203V_1 - 170$ (1)

node 2 $\frac{V_2 + 15}{1k} + \frac{V_2 + .7}{10} + \frac{V_2 - V_1}{2k} = 0$

$203V_2 - V_1 = -170$ (2)

(1)→(2): $41209 V_1 = 202 \cdot 170$

$V_1 = 0.833V$

$V_2 = -0.833V$

step ② $i_1 = (15 - V_1)/1k = 14.167mA$

$i_2 = i_3 = (V_1 - V_2)/2k = 0.833mA$

$i_4 = [V_2 - (-15)]/1k = 14.167mA$

$V_{D1} = V_1 = 0.833V$ $\quad i_{D1} = i_1 - i_2 = 13.33mA = (V_1 - .7)/10$ $\Rightarrow P_{D1} = Vi = 11.1W$

6. A shunt-connected DC motor (ie, the DC machine configuration in which the field windings and the armature are connected in parallel) has been determined to have the following full-load operating conditions:

- Rated Speed n_{rated} = 3000 rpm;
- Rated Torque T_{out} = 10 Nm;
- Terminal Voltage V_T = 70V;
- Line (input) Current I_L = 52A;
- Field Loss P_{field} = 140.0W;
- Frictional Loss P_{rot} = 158.4W.

(a) Under full-load conditions, determine the following:

[10 marks]

i. Field Current, I_F;
ii. Armature Current, I_A;
iii. Output Power, P_{out};
iv. Developed Power, P_{dev};
v. Armature EMF Voltage, E_A;
vi. Armature Loss, P_{Arm};
vii. Armature Resistance, R_A;
viii. Frictional Torque, T_{rot};
ix. Developed Torque, T_{dev};
x. Efficiency, η.

(b) Assuming frictional power loss to be constant, determine the speed regulation, SR, of this motor. Recall that speed regulations is given by:

$$SR = (n_{no\text{-}load} - n_{full\text{-}load}) / n_{full\text{-}load} \quad x\ 100\%$$

[x marks]

[1x marks total]

Solutions: (a)

i	Field Current, I_F	= 140W/70V = 2A
ii	Armature Current, I_A	= 52 – 2 = 50A
iii	Output Power, P_{out};	= 314.16 rad/s x 10Nm = 3141.6W, ω_{rated}=314.16 rad/s
iv	Developed Power, P_{dev};	= Prot +Pout = 3300W
v	Armature EMF Voltage, E_A	= 66V since Pdev = 3300W = E_A x 50A
vi	Armature Loss, P_{Arm}	= 70V x 50A – 3300W = 200W
vii	Armature Resistance, R_A	= 0.080 Ω since 200W = $50^2 R_A$ or R_A=(70V – 66V) / 50A
viii	Frictional Torque, T_{rot}	= P_{rot}/ω = 0.504 Nm
ix	Developed Torque, T_{dev}	= 10.504 NW
x	Efficiency, η	= 3141.6/(70x52) = 86.3%

(b) Assume friction constant, so at NL Pdev = 158.4 W ≈ 70V x I_A so I_A=2.26A so E_A= 69.82V so n = 3000 x 69.82/66 = 3174 rpm (if just used E_A≈70V get 3182rpm), so SR = 5.8%.