EE331

Electrical Engineering I

EXAM II

Monday April 2nd, 2012

This is a 50 minute exam. Please work quickly and quietly. Place your name below before beginning. There are 6 pages including this cover sheet. Please ensure that you have all 6 pages. Show as much work as practical to maximize partial credit. Eyes should remain on your own work. There is no sharing of calculators. **Do not discuss this exam until it is returned to you.** Please commence when advised.

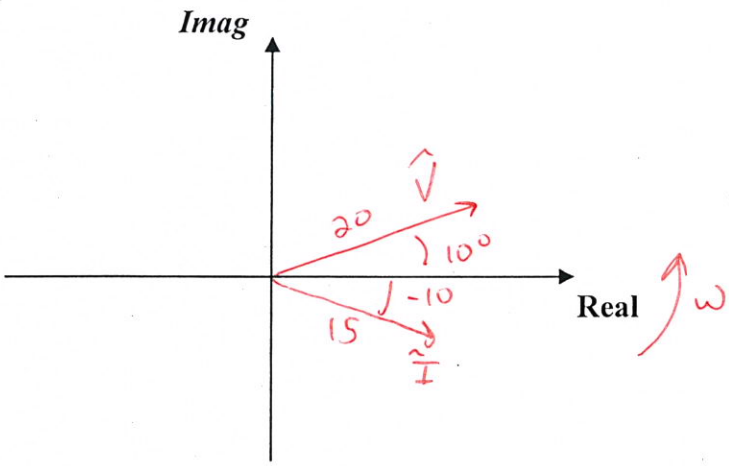
Page	Points	Score
1		
2	16	
3	12	
4	20	
5	14	
6	14	
Total	76	

NAME: Solution

SECTION: —

Problem 1 - Warm up #1 (8 pts): Given that $v(t) = 20*\cos(377t + 10)$ V, and $i(t) = 15*\sin(377t + 80)$, plot the phasors ($\bar{I}$ and $\bar{V}$) on the following diagram and answer the following questions.

15 cos(377t+80-90)

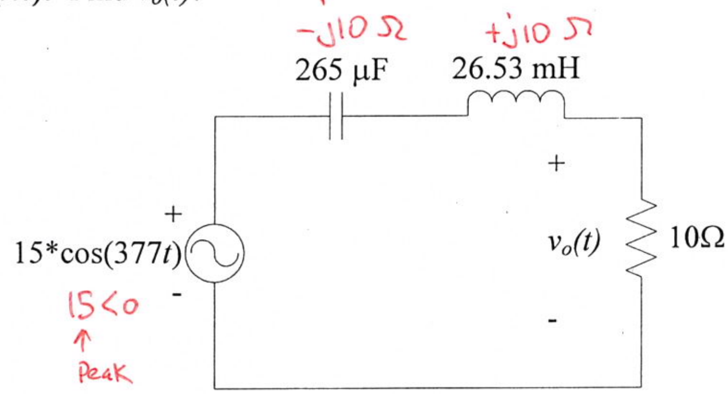


$\bar{I}$ **leads / lags / is in phase** with $\bar{V}$ (circle one)

Is this an overall **inductive / capacitive / resistive** circuit? (circle one)

ELI

Problem 2 (8 pts): Find $v_o(t)$.



$v_o(t) =$ 15cos(377t)

$$\tilde{V}_o = \frac{15\angle 0 \cdot 10\angle 0}{10} = 15\angle 0$$

Bonus(2 pts):

1) The current into a capacitor can change instantaneously. **True / False** (circle one)

2) If the current through a 10 mH inductor increases from zero to 2 A, how much energy is stored in the inductor?

$\frac{1}{2} L I^2 = \frac{1}{2} \cdot 10\text{m}H \cdot 2A^2 =$ 0.02 J

Problem 3: You are given a permanent magnet DC motor for use in an electric car that uses a 450 V battery. You run the following two tests:

Test 1: Apply 450 V_{DC} and you measure $I_a = 4$ A and $\omega = 200$ rad/s with no load

Test 2: Apply 450 V_{DC} and you measure $I_a = 300$ A and $\omega = 150$ rad/s with a load

a. **(8 pts)** Determine r_a, K_v, and T_{loss}.

Case 1:

$V_A - I_a r_a - K_v \omega = 0$

$450 - (4) \cdot r_a - K_v \cdot 200 = 0$

Case 2:

$V_A - I_a r_a - K_v \omega = 0$

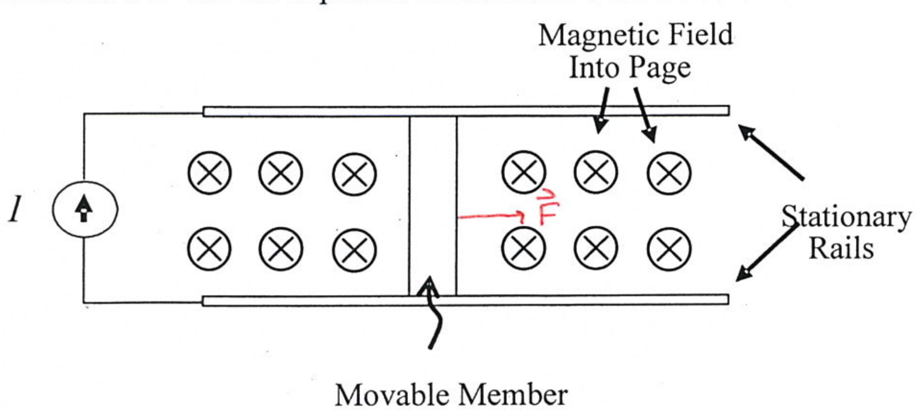
$450 - (300) r_a - K_v \cdot 150 = 0$

Solve: $K_v = 2.24$ V·S, $r_a = 0.38\,\Omega$

$\Rightarrow T_{loss} + T_{load} = K_v I_a = T_e$ (0 unloaded)

$T_{loss} = 2.24$ V·S · 4A = 8.96 N·m

Problem #4: Use the depiction of a linear DC motor below to answer the following questions.



TRUE ~~(FALSE)~~ **(2pts)** With the given current and magnetic field direction, the force on the movable member would be to the left.

TRUE (FALSE) **(2pts)** Greater acceleration can be generated if the stationary rails are lengthened.

$F = ILB$

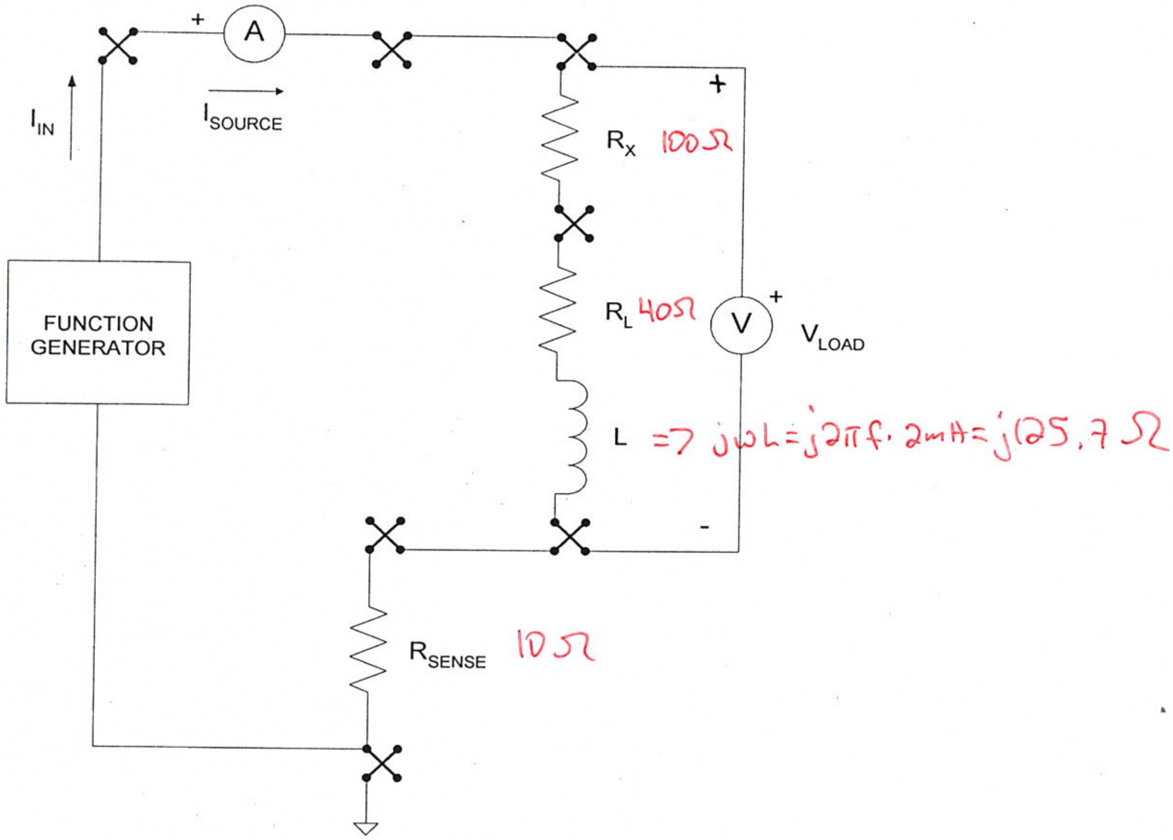
Bonus (2 pts): If the movable member's mass = 20 kg, its length = 1 m, B = 10 T, and I = 1000 A, how much time will it take to achieve a velocity = 500 m/s?

$F = ILB = 1000\text{A} \cdot 1\text{m} \cdot 10 = 10{,}000\text{ N} = ma$

$\Rightarrow a = \frac{10{,}000\text{N}}{20\text{kg}} = 500\text{ m/s}^2 \Rightarrow V = \int a\,dt = at \Rightarrow$ t = 1 Second

Problem 5 (20 pts): Given the single phase AC circuit below where $V_{load} = 5<0\ V_{rms}$, f = 10 kHz, $R_{sense} = 10\ \Omega$, $R_L = 40\ \Omega$, L = 2 mH, and $R_x = 100\ \Omega$ compute the requested quantities:

******Note the load does not include R_{sense}******



- $\hat{I}_{Load} = \dfrac{5<0}{140+j125.7} = 0.0266<-41.9^\circ\ A_{rms}$

- $\hat{S}_{Load} = 5<0 \cdot 0.0266<+41.9^\circ = 0.133<41.9^\circ\ VA = 99 + j88.8\ mVA$

Z_{Load} = 140 + j125.7 Ω

I_{Load} = 0.0266 <-41.9° A_{RMS}

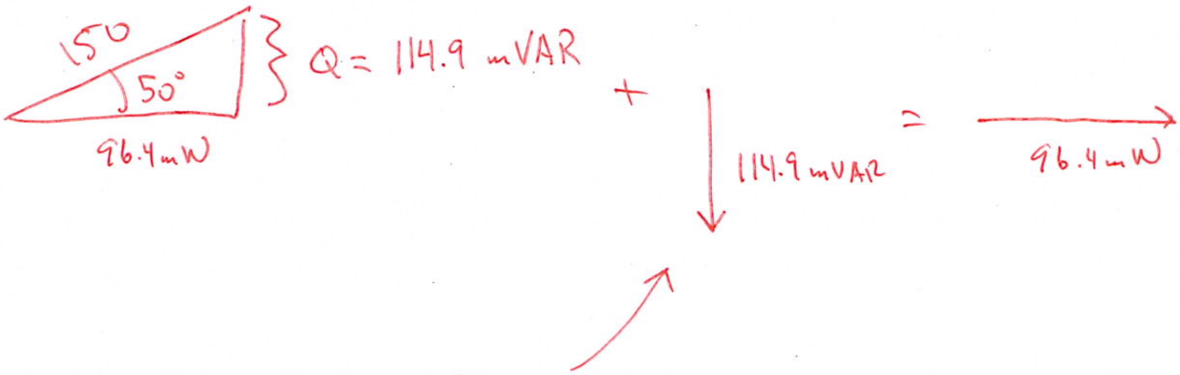
S_{Load} = 99 + j88.8 mVA

P_{Load} = 99 mW

Q_{Load} = 88.8 mVAR

Power Factor of Load = 0.74 Lagging

Problem 6 (10 pts): Assuming that $\overline{S}_{Load}$ = 150<50 mVA for the previous problem (this may or may not be the case), determine the capacitance required to achieve a unity power factor.



$$Q_c = \frac{V^2}{|Z_c|} = \omega C V^2 \Rightarrow C = \frac{Q_c}{\omega V^2} = \frac{114.9}{(2\pi \cdot 10{,}000) \cdot 5^2} = \boxed{73.1\,nF}$$

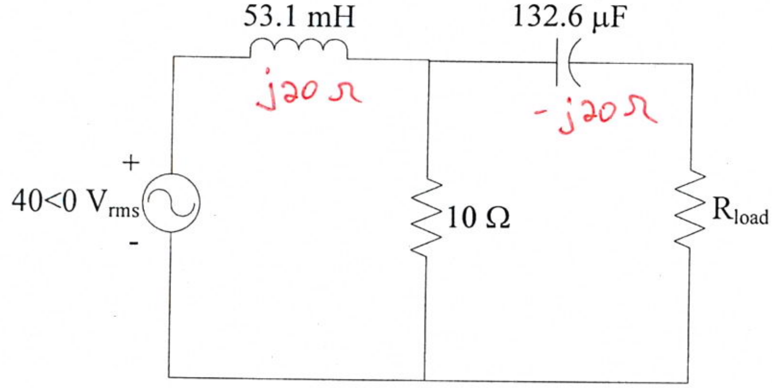
Question (4 pts): Before the power factor correction, does the source voltage lead or lag the total current? By how much does the source voltage lead or lag?

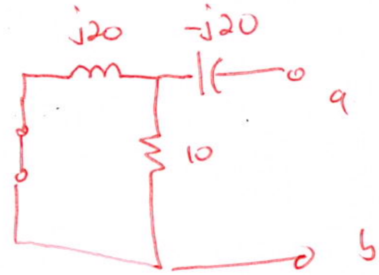
ELI

$\theta_z > 0$, Inductive $\Rightarrow$ **Voltage leads by 50°**

$\theta_z = \theta_v - \theta_i$

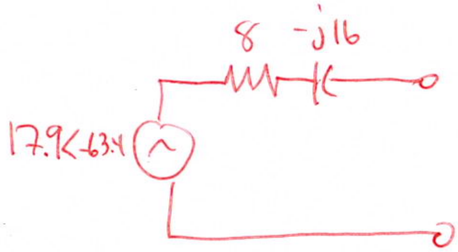
Problem 7 (14 pts): **Find** and **draw** the Thevenin equivalent circuit for R_{load} assuming f = 60 Hz.





- $Z_{th} = -j20 + \underbrace{j20 \,//\, 10}_{8+j4} = 8 - j16 = 17.9\angle{-63.4^\circ}$

- $\hat{V}_{th} = \hat{V}_{oc} = \dfrac{40\angle 0 \cdot 10\angle 0}{10 + j20} = 17.9\angle{-63.4^\circ}\ V$



Bonus Problem (2 pts): What should the load be (include specific component values, resistance, inductance, and capacitor values) for maximum power delivery?

$Z_{th}^{*} = Z_{Load\ max\,power} = 8 + j16$

$j\omega L \Rightarrow L = \frac{16}{377} = 42.4\,mH$