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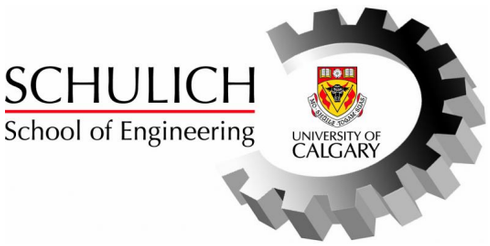

ENGG 225 - Fundamentals of Electrical Circuits and Machines

Final Examination

Monday, April 18, 2011
Time: 3:30 - 6:30 PM

Red and Auxiliary Gymnasium

L01, L02 - *Norm Bartley*
L03 - *Hamid Zareipour*
L04 - *Pouyan (Yani) Jazayeri*
L05 - *Anis Haque*
L06 - *Anders Nygren*

Instructions:

- Time allowed is 3 hours.
- Please review the examination rules on Page 2.
- The examination is closed-book and closed-notes.
- Only calculators sanctioned by the Schulich School of Engineering are permitted in the examination.
- The maximum number of marks is 100, as indicated. The final examination counts toward 50% of the final grade. Please attempt all six questions.
- Please use a pen or heavy pencil to ensure legibility.
- Please answer questions in the spaces provided; if space is insufficient, please use the back of the pages.
- Where appropriate, marks will be awarded for proper and well-reasoned explanations.

(Please do not write in this space.)

#1 *(18)*	**#2** *(18)*	**#3** *(18)*	**#4** *(18)*	**#5** *(18)*	**#6** *(10)*	**Total** *(100)*

Student Identification

Each candidate must sign the Seating List confirming presence at the examination. All candidates for final examinations are required to place their University of Calgary I.D. cards on their desks for the duration of the examination. (Students writing mid-term tests can also be asked to provide identity proof.) Students without an I.D. card who can produce an **acceptable** alternative I.D., e.g., one with a printed name and photograph, are allowed to write the examination.

A student without acceptable I.D. will be required to complete an Identification Form. The form indicates that there is no guarantee that the examination paper will be graded if any discrepancies in identification are discovered after verification with the student's file. **A student who refuses to produce identification or who refuses to complete and sign the Identification Form is not permitted to write the examination.**

Examination Rules

(1) Students late in arriving will not normally be admitted after one-half hour of the examination time has passed.

(2) No candidate will be permitted to leave the examination room until one-half hour has elapsed after the opening of the examination, nor during the last 15 minutes of the examination. All candidates remaining during the last 15 minutes of the examination period must remain at their desks until their papers have been collected by an invigilator.

(3) All inquiries and requests must be addressed to supervisors only.

(4) **The following is strictly prohibited:**

   (a) speaking to other candidates or communicating with them under any circumstances whatsoever;
   (b) bringing into the examination room any textbook, notebook or document not authorized by the examiner;
   (c) making use of calculators, cameras, cell-phones, computers, headsets, pagers, PDA's, or any device not authorized by the examiner;
   (d) leaving examination papers exposed to view;
   (e) attempting to read other student's examination papers.

   The penalty for violation of these rules is suspension or expulsion or such other penalty as may be determined.

(5) Candidates are requested to write on both sides of the page, unless the examiner has asked that the left hand page be reserved for rough drafts or calculations.

(6) Discarded matter is to be struck out and not removed by mutilation of the examination answer book.

(7) Candidates are cautioned against writing on their examination paper any matter extraneous to the actual answering of the question set.

(8) The candidate is to write his/her name on each answer book as directed and is to number each book.

(9) During the examination a candidate must report to a supervisor before leaving the examination room.

(10) Candidates must stop writing when the signal is given. Answer books must be handed to the supervisor-in-charge promptly. Failure to comply with this regulation will be cause for rejection of an answer paper.

(11) If during the course of an examination a student becomes ill or receives word of a domestic affliction, the student should report at once to the supervisor, hand in the unfinished paper and request that it be cancelled. If physical and/or emotional ill health is the cause, the student must report at once to a physician/counsellor so that subsequent application for a deferred examination is supported by a completed Physician/Counsellor Statement form. Students can consult professionals at University Health Services or Counselling and Student Development Centre during normal working hours or consult their physician/counsellor in the community. **Once an examination has been handed in for marking a student cannot request that the examination be cancelled for whatever reason. Such a request will be denied. Retroactive withdrawals will also not be considered.**

1. Consider the DC circuit shown in Fig. 1.

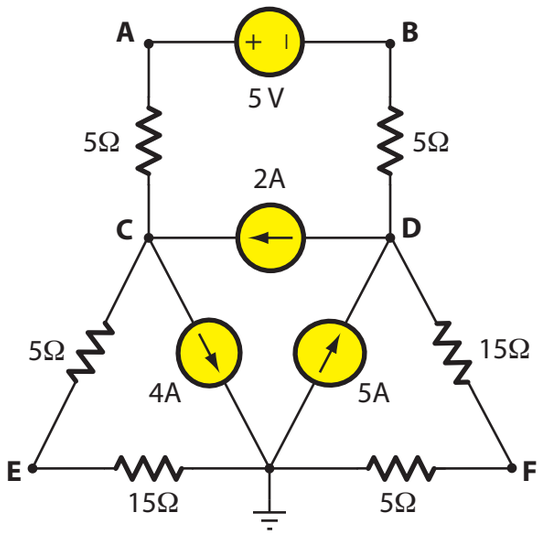

Fig. 1. Find the node voltages; confirm energy balance.

(a) Use any method of your choosing to determine all of the indicated node voltages. **[10 marks.]**

(b) Using your answers to part (a), calculate the total power in the circuit, and confirm that the total power is zero. *(Note: If you are unable to determine the node voltages in part (a), you may assume any reasonable values to solve this part.)* **[8 marks.]**

[18 marks total.]

(Problem #1 extra workspace.)

2. Consider the steady-state sinusoidal AC circuit shown in Fig 2. The voltage sources are:

$$v_1(t) = 20\cos(1000t)\ V,$$
$$v_2(t) = 10\cos(1000t + 90^\circ)\ V.$$

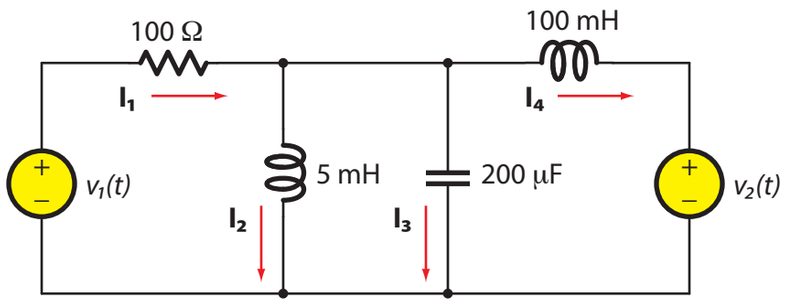

Fig. 2. Find $\mathbf{I}_1$, $\mathbf{I}_2$, $\mathbf{I}_3$, $\mathbf{I}_4$; *determine P, Q, apparent power, and power factor in* $v_1(t)$.

(a) Find the phasor currents $\mathbf{I}_1$, $\mathbf{I}_2$, $\mathbf{I}_3$, $\mathbf{I}_4$, and show them on a phasor diagram (it is not necessary to draw the diagram to scale). **[12 marks.]**

(b) Using whatever you determined for $\mathbf{I}_1$ in part (a), calculate the average power (i.e., "active" power), reactive power, apparent power, and power factor in the source $v_1(t)$. Is the power factor *leading* or *lagging*?

[6 marks.]

[18 marks total.]

(Problem #2 extra workspace.)

3. For the resistor-inductor circuit shown in Fig. 3, assume that the switch has been open for a long time and that the circuit is in DC steady-state. The switch is then closed at time $t = 0$.

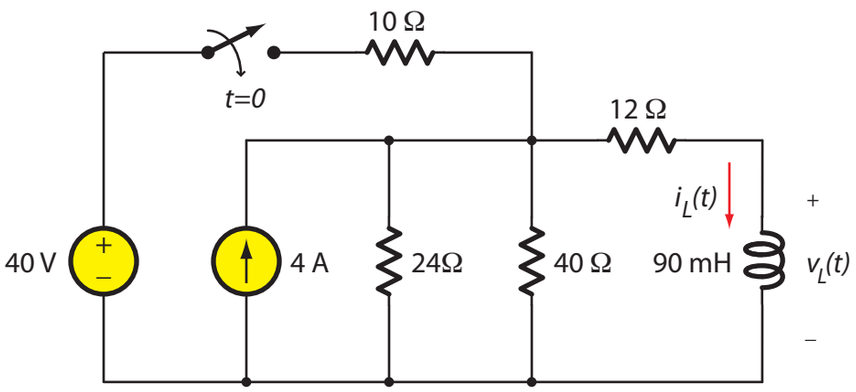

Fig. 3. Find and sketch $i_L(t)$ and $v_L(t)$

(a) Determine the expression for $i_L(t)$, $t \geq 0$, and sketch $i_L(t)$ for $t \geq$ -1 ms. Indicate the $i_L(t = \tau)$ point on the curve. (Recall that $\tau = L/R$.)

[9 marks.]

(b) Determine the expression for $v_L(t)$, $t \geq 0$, and sketch $v_L(t)$ for $t \geq$ -1 ms. Indicate the $v_L(t = \tau)$ point on the curve. **[5 marks.]**

(c) Suppose that the switch is opened again at $t = 6$ ms. Determine the expression for $i_L(t)$ for $t \geq 6$ ms. (It is not necessary to sketch this.)

[4 marks.]

[18 marks total.]

(Problem #3 extra workspace.)

4. The op-amps in Fig. 4 are ideal and are operating in their linear regions.

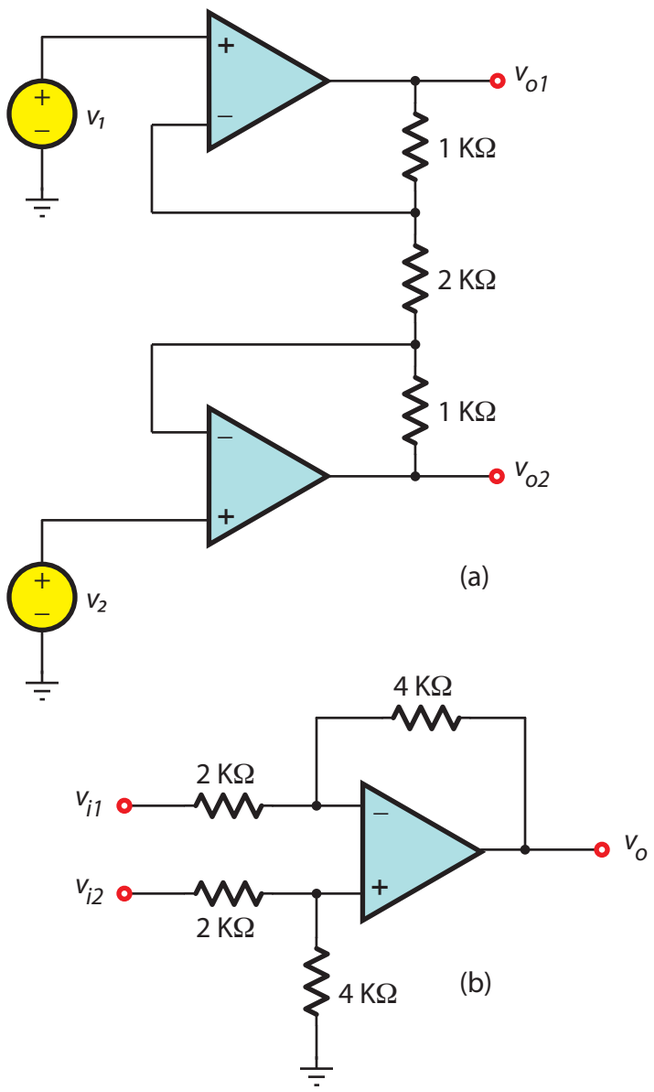

Fig. 4. Find v_{o1} and v_{o2} in part (a); then find v_o in part (b).

(a) For the circuit in Fig. 4(a), determine the node voltages v_{o1} and v_{o2} in terms of the source voltages v_1, v_2. **[8 marks.]**

(b) Using whatever you calculated in part (a) for v_{o1} and v_{o2}, connect these two nodes to the input nodes v_{i1} and v_{i2}, respectively, of the circuit in Fig. 4(b). Determine the output node voltage v_o. *(Note: If you are unable to find a solution to part (a), solve for v_o in terms of node voltages v_{i1} and v_{i2}.)* **[10 marks.]**

[18 marks total.]

(Problem #4 extra workspace.)

5. Consider the steady-state sinusoidal AC circuit in Fig. 5, which operates at a frequency of $\omega = 2000$ rads/sec.

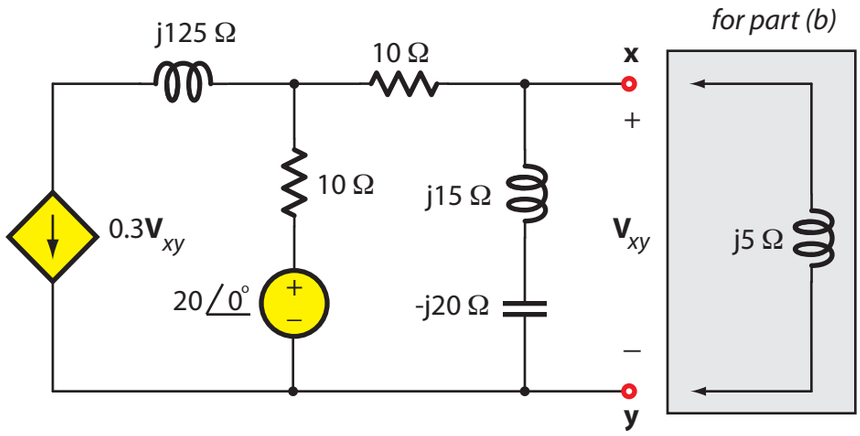

Fig. 5. Find the Thévenin equivalent; then find $v_{xy}(t)$ with the inductor attached, assuming $\omega = 2000$ rad/sec.

(a) Determine the Thévenin equivalent circuit to the left of the terminals **x** and **y**. Express the Thévenin voltage in phasor form $\mathbf{V}_T$ and give the Thévenin impedance Z_T. **[11 marks.]**

(b) Find the time-domain expression for $v_{xy}(t)$ when the inductor is attached as shown in Fig. 5. **[4 marks.]**

(c) Sketch a circuit implementation of Z_T. If there is a capacitive or inductive component, give its value in Farads or Henrys, respectively. **[3 marks.]**

[18 marks total.]

(Problem #5 extra workspace.)

6. A shunt-connected DC motor (i.e., the DC machine configuration in which the field windings and the armature are connected in parallel) has the following full-load specifications:

   - Terminal voltage for armature and field circuits is $V_T = 200$ V;
   - Output torque at rated speed is $T_{out} = 40$ Nm;
   - Frictional torque loss at rated speed is $T_{rot} = 2$ Nm;
   - Total field resistance $R_{adj} + R_F = 100\Omega$;
   - Armature resistance $R_A = 0.5\Omega$;
   - Total input line current $I_L = 102$ A.

   Recall the basic machine equations $E_A = K\phi\omega_m$, $T_{dev} = K\phi I_A$, and $P = T\omega_m$. Under these full-load conditions, and at rated speed, determine the following:

   (a) The field current I_F and armature current I_A;

   (b) Rated speed n_m, in rpm (1 rpm = $\frac{60}{2\pi}$ rads/sec);

   (c) The developed power P_{dev} and output power P_{out} in HP (1 HP = 746 W);

   (d) The power lost in the field resistance $P_{field-loss}$ and armature resistance $P_{arm-loss}$;

   (e) The efficiency η.

   [10 marks total.]