Last Name: _____ *Lecture Section:* _____

First Name: _____

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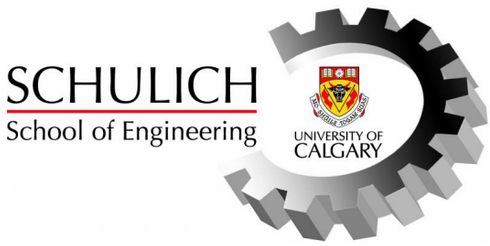


ENGG 225 - Fundamentals of Electrical Circuits and Machines

Winter 2018 Final Examination

Saturday, April 21, 2018
Time: 12:00 - 3:00 PM

Red Gymnasium (L01, L02)
Gold Gymnasium (L03, L04)

L01 - *Pouyan (Yani) Jazayeri*
L02 - *Norm Bartley*
L03 - *Denis Onen*
L04 - *Mike Potter*

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 (Casio FX-260, Casio FX-300MS, or TI-30XIIS) 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 *(28)*	**#2** *(12)*	**#3** *(16)*	**#4** *(14)*	**#5** *(18)*	**#6** *(12)*	**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.

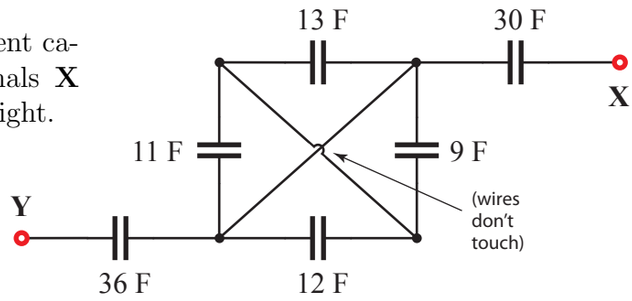
(9) During the examination a candidate must report to a supervisor before leaving the examination room.

(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 UC Wellness Center 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.**

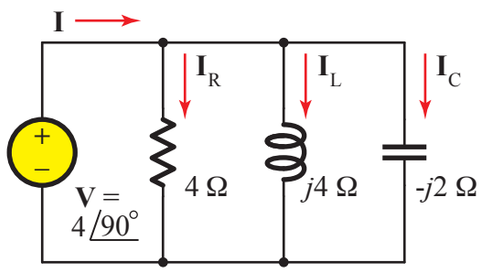
1. **[28 marks.]** Parts (a)-(g) below each have an identical weighting of four marks. Please answer the questions in the boxes provided. *(Note: In problems needing answers in complex form, you may use either polar or rectangular notation.)*

(a) **[4]** Determine the total equivalent capacitance C_{XY} between terminals **X** and **Y** in the circuit shown at right.

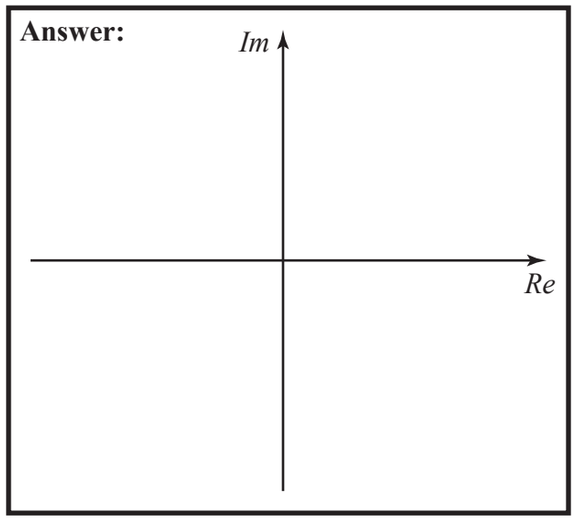


Answer: $C_{XY} =$

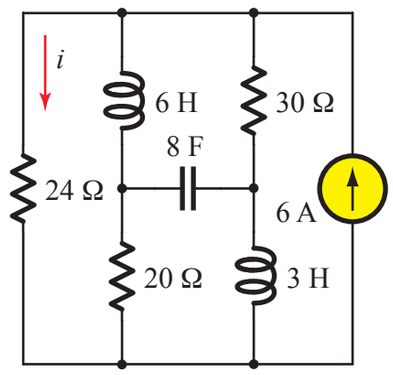
(b) **[4]** For the circuit given at right, complete the phasor diagram given below to show $\mathbf{I}$, $\mathbf{I}_R$, $\mathbf{I}_L$, and $\mathbf{I}_C$. Carefully label each phasor.



Answer:

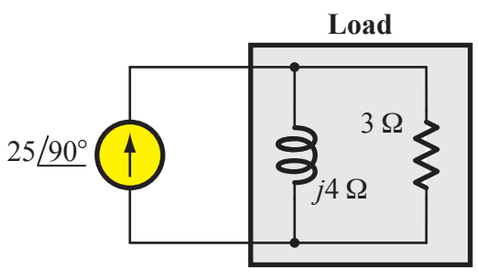


(c) **[4]** The current source in the circuit at right is *DC* and provides 6 Amperes. Determine the current i.



Answer: $i =$

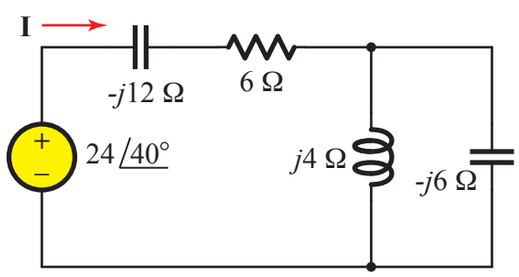
(d) **[4]** Determine the complex power **S** in the load impedance in the circuit at right, and indicate whether the power factor is leading or lagging.



Answer: **S** =

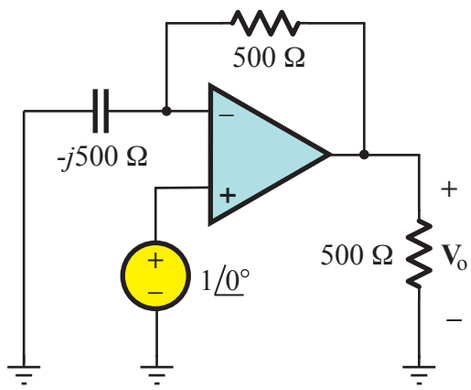
Answer: *leading / lagging*

(e) **[4]** In the circuit given at right, determine the phasor current **I**.



Answer: **I** =

(f) **[4]** The op-amp in the circuit at right is ideal and is operating in its linear region. Determine the phasor output voltage $\mathbf{V}_o$.



Answer: $\mathbf{V}_o =$

(g) **[4]** Suppose that an AC load has an apparent power $P_{app} = 20$ VA, and has a power factor of 0.5 *leading*. Sketch the power triangle, and determine the reactive power Q.

Answer: $Q =$

2. [**12 marks.**] For the circuit shown in Fig. P2, find i by superposition.

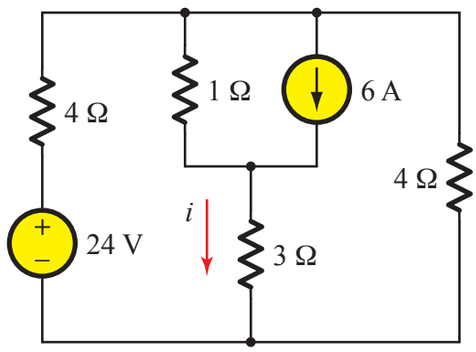


Fig. P2. Find current i by superposition.

3. **[16 marks.]** Consider the inductor indicated below in Fig. P3. The current through the inductor $i_L(t)$ and the voltage across the inductor $v_L(t)$ are known to be zero for $t < 0$. The current through the inductor for $t \geq 0$ is as shown.

   - Determine expressions for the voltage $v_L(t)$ for all intervals of t;
   - then carefully sketch and properly label graphs for $v_L(t)$, the power $p_L(t)$, and the energy $w_L(t)$ for $t \geq 0$.

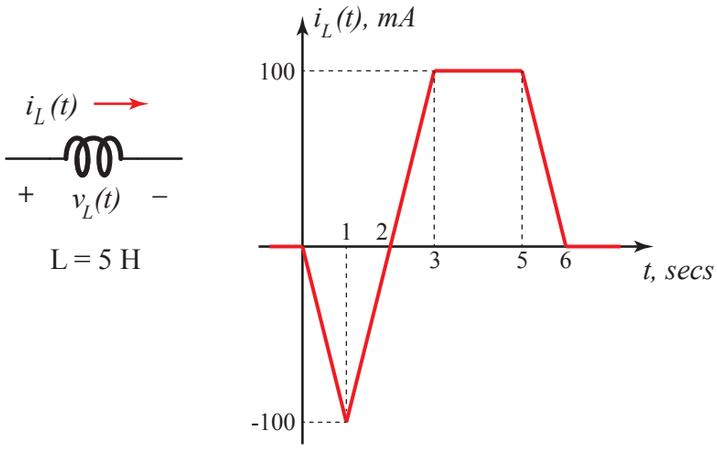


Fig. P3. Determine and sketch $v_L(t)$, $p_L(t)$, and $w_L(t)$.

(Problem #3 extra workspace.)

4. **[14 marks.]** The op-amps in this problem are ideal and operate in their linear regions.

   The circuit in Fig. P4 has an important practical application in interfacing digital electronic circuits with analog circuits. As shown, there are four input source voltages v_1, v_2, v_3, and v_4, each of which can be set to only *one* of two possible voltage levels: 0.0 V or 1.0 V.

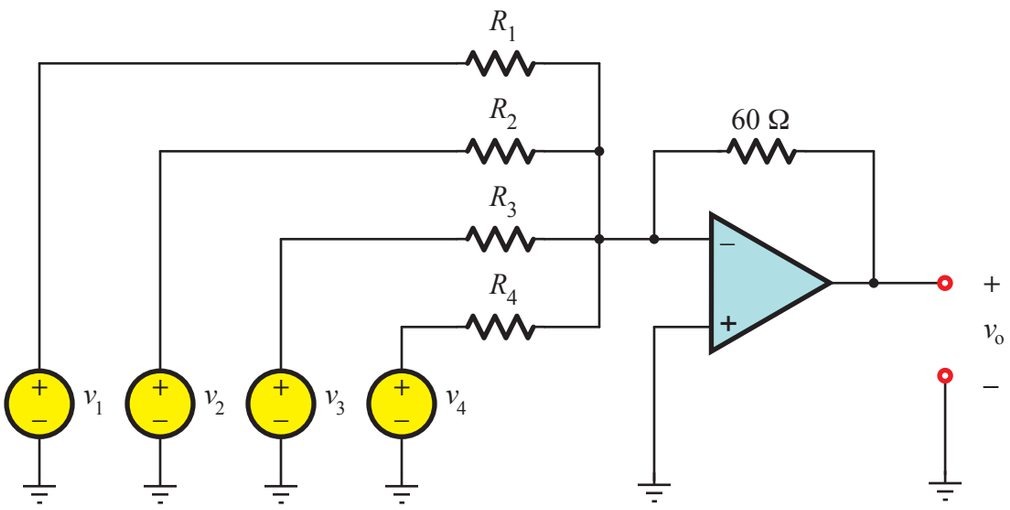


Fig. P4. A simple "Digital-to-Analog Converter" circuit.

(a) **[8]** A list of all possible combinations of the input source voltages is given in the table at right along with the required output voltage v_o for each. For example, the second row has input values of v_1, v_2, v_3, and v_4 = 0, 0, 0, and 1 V, respectively. The resulting output value is $v_o = -1$ V. Find the resistor values for R_1, R_2, R_3, and R_4, which satisfy the table.

(Hint: To start, separately analyze the cases when $v_o = -1$, $v_o = -2$ V, $v_o = -4$ V, and $v_o = -8$ V.)

Input sources				**Output**
v_1	v_2	v_3	v_4	v_o
0	0	0	0	0
0	0	0	1	-1
0	0	1	0	-2
0	0	1	1	-3
0	1	0	0	-4
0	1	0	1	-5
0	1	1	0	-6
0	1	1	1	-7
1	0	0	0	-8
1	0	0	1	-9
1	0	1	0	-10
1	0	1	1	-11
1	1	0	0	-12
1	1	0	1	-13
1	1	1	0	-14
1	1	1	1	-15

(b) **[6]** Design a second op-amp circuit that connects to v_o above, and produces an output voltage v_c such that $v_c = -v_o$. Use resistor values of not less that 500 Ω.

(Problem #4 extra workspace.)

5. **[18 marks.]** Consider the steady-state sinusoidal analysis of the circuit shown in Fig. P5, where each source operates at a frequency of $f = 50/\pi$ Hz. Z_1 is the impedance of a 1 mF capacitor. $\mathbf{I}_1$ has an *rms* value of 2 A, and it *leads* $\mathbf{V}_1$ by 60°. All other sources in this problem are given in terms of *peak* values.

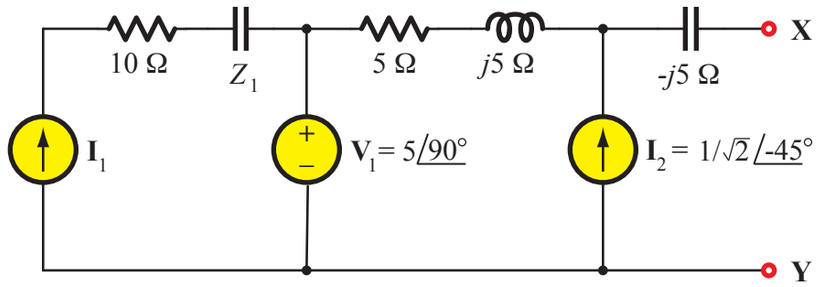


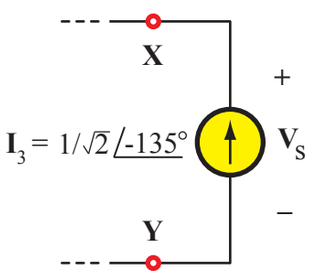
Fig. P5. Find the Thévenin equivalent circuit.

(a) **[4]** Determine the following in the above circuit:

- the impedance Z_1;
- the phasor representation of $\mathbf{I}_1$;
- the time-domain expression for $i_2(t)$.

(b) **[10]** Determine the Thévenin equivalent circuit at the terminals **X** and **Y**. You may express your answer in either polar or rectangular form.

(c) **[4]** If a current source $\mathbf{I}_3$ is connected to terminals **X** and **Y** in the circuit above, calculate the phasor voltage $\mathbf{V}_S$ across this source. The value and direction of $\mathbf{I}_3$ is shown at right. You may express your answer in either polar or rectangular form.



(Problem #5 extra workspace.)

6. **[12 marks.]** Consider the separately excited DC motor shown in Fig. P6, with the steady-state full-load specifications as indicated. You may assume that the rotational losses for this machine are negligable.

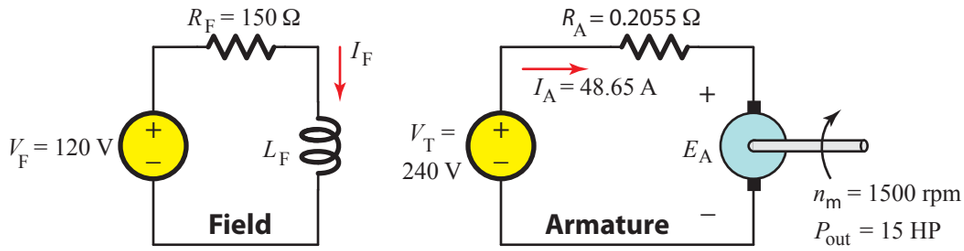


Fig. P6. Full-load specifications for a separately excited DC motor.

Recall the basic machine equations $E_A = K\phi\omega_m$, $T_{dev} = K\phi I_A$, and $P = T\omega_m$. (Also, $\omega_m = 2\pi n_m/60$ and 1 HP = 746 W.)

(a) **[6]** Suppose that the motor is operating at rated capacity to help propel a hybrid electric vehicle up a hill. Under full-load conditions, find the output torque T_{out}, the induced voltage E_A, field power loss P_F, armature power loss P_A, and efficiency η.

(b) **[6]** Now imagine that the vehicle is descending rapidly on the other side of the hill, and that physical torque *reverses* on the motor shaft. The new value is T_{out}= -30 Nm (i.e., *negative* 30 Nm). Determine the power in the 240 V source, and indicate if the source is absorbing or delivering power.