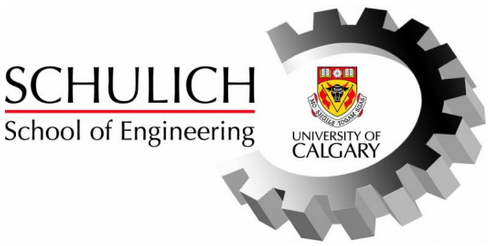
Name: _____ *Lecture Section:* _____

ID#: _____



ENGG 225 - Fundamentals of Electrical Circuits and Machines

Final Examination

Tuesday, April 28, 2015
Time: 12:00 - 3:00 PM

Red Gymnasium (L01-L03)
Auxiliary Gymnasium (L04)

L01 - *Norm Bartley*
L02 - *Brent Maundy*
L03 - *Pouyan (Yani) Jazayeri*
L04 - *Anis Haque*

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 five 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 *(24)*	**#2** *(18)*	**#3** *(22)*	**#4** *(21)*	**#5** *(15)*	**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.

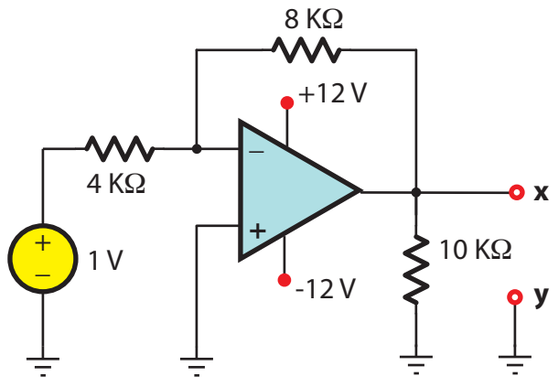
(9) During the examination a candidate must report to a supervisor before leaving the examination room.

(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.**

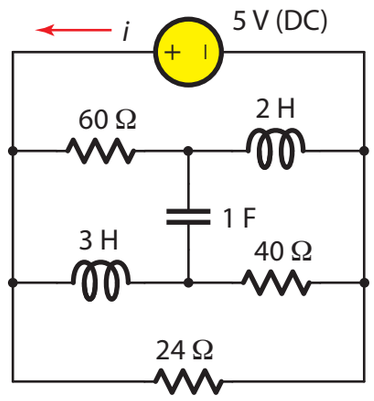
1. **[24 marks.]** Parts (a)-(h) below each have an identical weighting of three marks. Please answer the questions in the boxes provided.

(a) **[3]** For the op-amp circuit given at right, determine the Thévenin resistance R_t to the left of the terminals **x** and **y**.



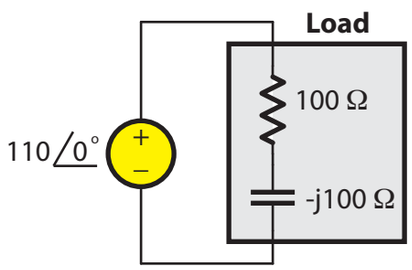
Answer: $R_t =$

(b) **[3]** The DC voltage source in the circuit at right produces 5 Volts. Determine the current i.



Answer: $i =$

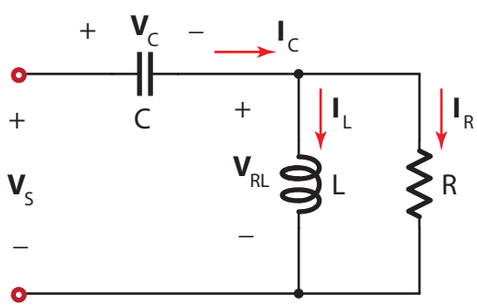
(c) **[3]** Calculate the complex power **S** in the electrical load indicated in the circuit at right.



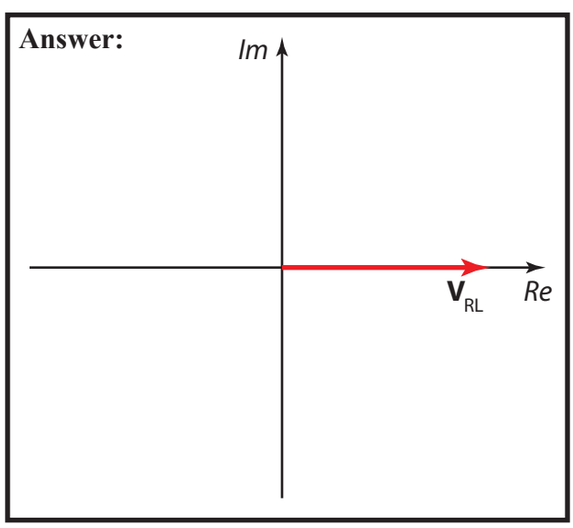
Answer: **S** =

(Problem #1 continued.)

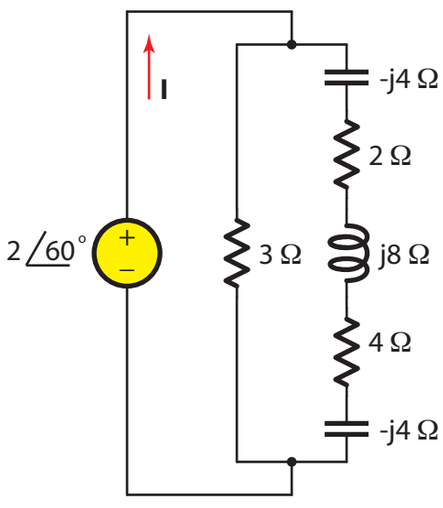
(d) **[3]** In the circuit given at right, we are given that $|\mathbf{I}_L| = |\mathbf{I}_R|$, and that $|\mathbf{V}_C| = |\mathbf{V}_{RL}|$. In the space provided below, sketch the phasor diagram indicating *just the phase relationship* between $\mathbf{I}_R$, $\mathbf{I}_L$, $\mathbf{I}_C$, $\mathbf{V}_C$, and $\mathbf{V}_S$ (their magnitudes are not important). Use $\mathbf{V}_{RL}$ as the reference vector, as shown.



Answer:



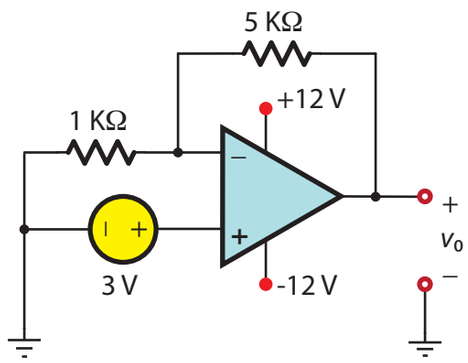
(e) **[3]** In the circuit given at right, determine the phasor current $\mathbf{I}$.



Answer: $\mathbf{I}$ =

(Problem #1 continued.)

(f) **[3]** In the op-amp circuit given at right, determine v_o.



Answer: $v_o =$

(g) **[3]** A load connected to an AC source absorbs 15 W of power with a power factor (PF) of 0.7 *leading*. Sketch the power triangle, and determine the appropriate values of P, Q, θ, and the apparent power $|\mathbf{S}|$.

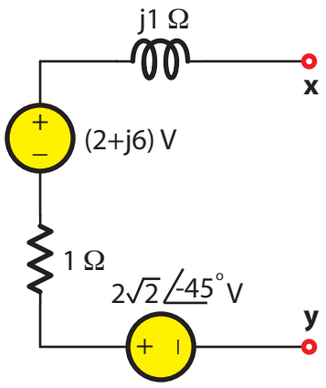
Answer: $P =$

Answer: $Q =$

Answer: $\theta =$

Answer: $|\mathbf{S}| =$

(h) **[3]** Convert the the circuit given at right to an equivalent circuit that has one current source instead of the two voltage source. Sketch your answer in the blank space below.

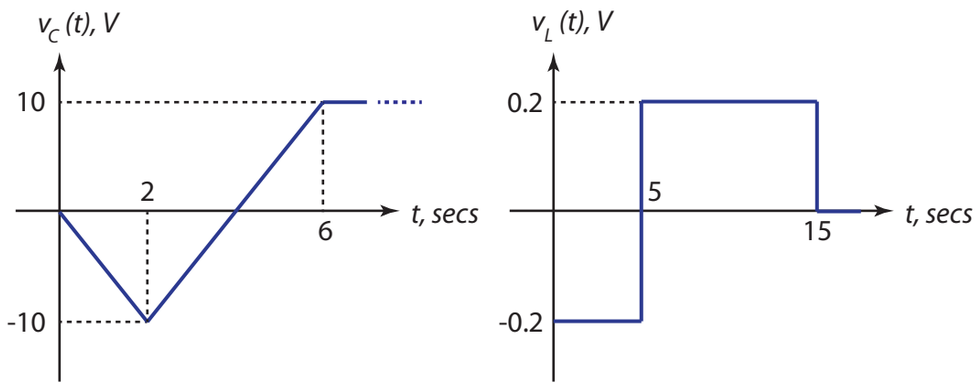


2. **[18 marks.]** Consider the capacitor and inductor in Fig. P2.

   (a) **[9]** For the capacitor in Fig. P2(a), determine and carefully sketch the current $i_C(t)$, the power $p_C(t)$, and energy $w_C(t)$ for $t \geq 0$ in response to the voltage waveform $v_C(t)$. There is no initial charge on the capacitor.

   (b) **[9]** For the inductor in Fig. P2(b), determine and carefully sketch the current $i_L(t)$ and power $p_L(t)$ for $t \geq 0$ in response to the voltage waveform $v_L(t)$. The initial current in the inductor is $i_L(0) = -1$ A.

Fig. P2. Part (a), sketch $i_C(t)$, $p_C(t)$, $w_C(t)$; Part (b), sketch $i_L(t)$, $p_L(t)$.



(Problem #2 extra workspace.)

3. **[22 marks.]** Consider the op-amp circuit below in Fig. P3(a).

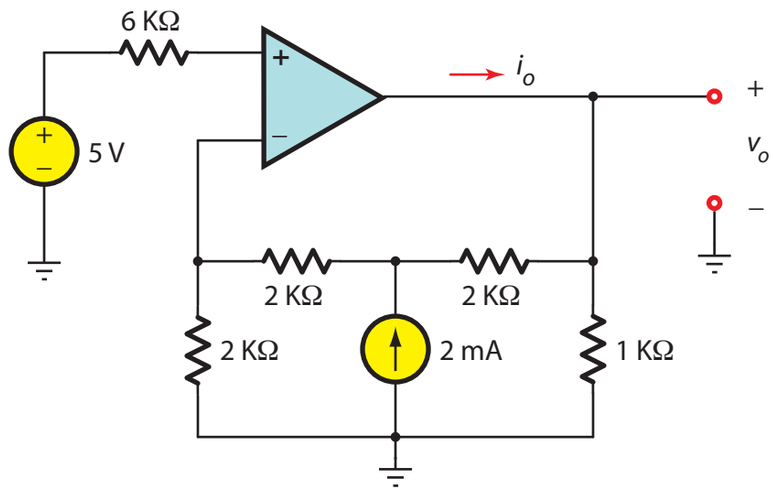


Fig. P3(a). Find v_o and i_o in parts (a) and (b).

(a) **[9]** The op-amp in Fig. P3(a) is ideal and is operating in its linear region. Determine the output voltage v_o.

(b) **[4]** Using your answer to part (a), determine i_o for the op-amp.

Please see part (c), next page.

(Problem #3 continued.)

(c) [**9**] Suppose that you set out to build the circuit of Fig. P3(a) with an early prototype op-amp. A very simple circuit model for this op-amp is shown in the boxed area of Fig. 3(b). Use this simple model with $A = 100$ to calculate the new output voltage v_o as well as the op-amp's differential input voltage v_d.

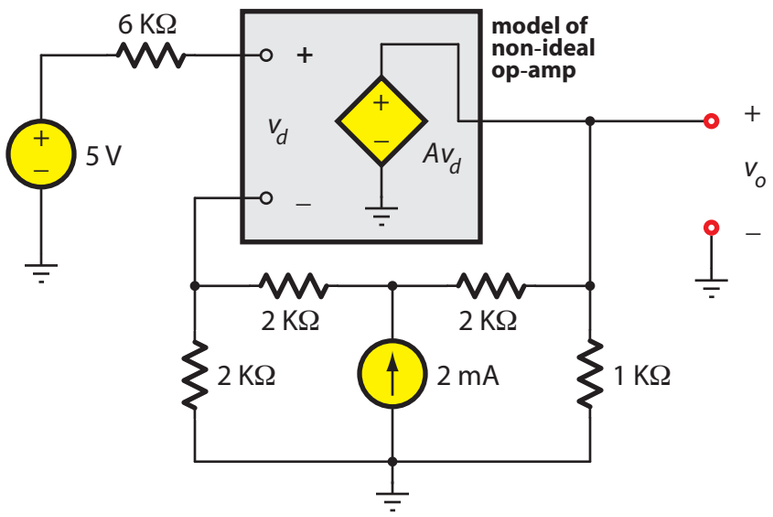


Fig. P3(b). Find v_o and v_d using given op-amp model with $A = 100$.

4. **[21 marks.]** Consider the AC circuit shown in Fig. P4. The three sources operate at $f = 60$ Hz, and are defined as follows:

   - $v_2(t) = 10\sqrt{2}\sin(\omega t)$ V.
   - $v_1(t)$ has an rms value of 10 V and *leads* $v_2(t)$ by 90°.
   - $i_1(t)$ has a peak value of 2 A and *leads* $v_2(t)$ by 90°.

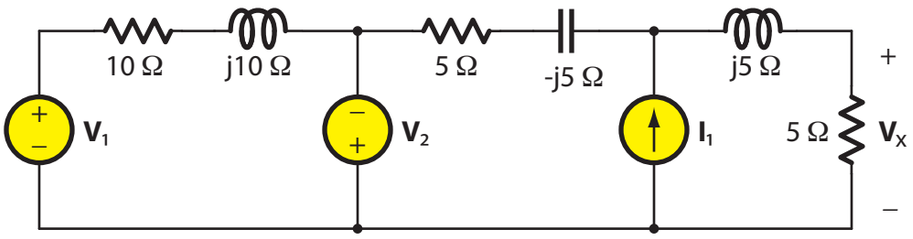
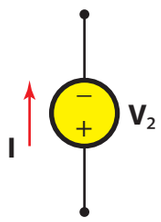


Fig. P4. Find $\mathbf{V}_x$ *by superposition.*

(a) **[13]** Find $\mathbf{V}_\mathrm{X}$ by superposition (you may express this in either polar or rectangular form).

(b) **[4]** Show $\mathbf{I}_1$, $\mathbf{V}_1$, $\mathbf{V}_2$, and $\mathbf{V}_\mathrm{X}$ on a phasor diagram.

(c) **[4]** Let the current through the source $\mathbf{V}_2$ be given by $\mathbf{I} = 5\sqrt{2}\angle -45°$ as shown at right. Determine the real power P_2 and reactive power Q_2 in this source. Give the power factor and whether it is leading or lagging.



(Problem #4 extra workspace.)

5. **[15 marks.]** Consider the shunt-connected DC motor shown in Fig. P5, with the steady-state full-load specifications as indicated.

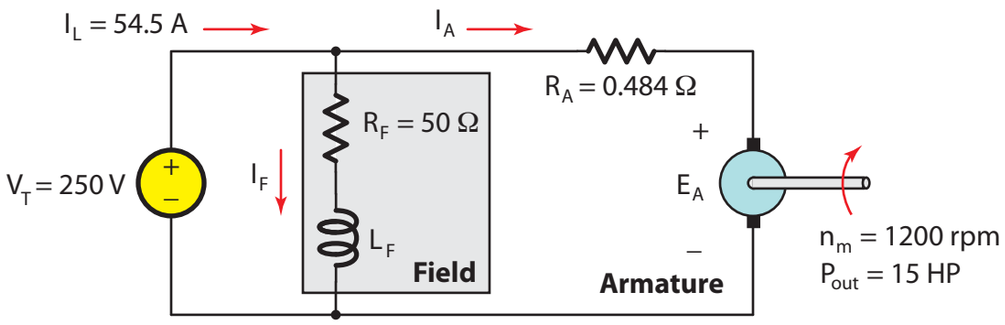


Fig. P5. Shunt-connected DC motor configuration.

Assume for parts (a) and (b) that the rotational losses for this motor are negligible. 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]** Under full load conditions, find the output torque T_{out}, field power loss P_F, armature power loss P_A, the induced voltage E_A, and the efficiency η.

(b) **[4]** If the motor is initially powered down with $n_m = 0$, determine the output torque T_{out} and power P_{out} at the instant that power is switched on to the motor.

(c) **[5]** Suppose that fan blades have been attached to the motor's shaft to help cool the motor while it is driving the mechanical load. Assume that the fan causes a constant rotational torque loss of $T_{rot} = 10$ Nm. Calculate the new motor speed n_m in rpm with the cooling fan now attached.