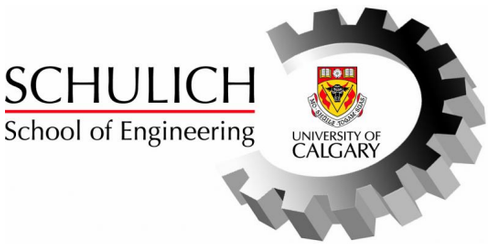
Name: _____ *Lecture Section:* _____

ID#: _____



ENGG 225 - Fundamentals of Electrical Circuits and Machines

Final Examination

Monday, April 22, 2013
Time: 12:00 - 3:00 PM

Red and Gold Gymnasium

L01 - *Anis Haque*
L02 - *Norm Bartley*
L03 - *Michel Fattouche*
L04 - *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 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.

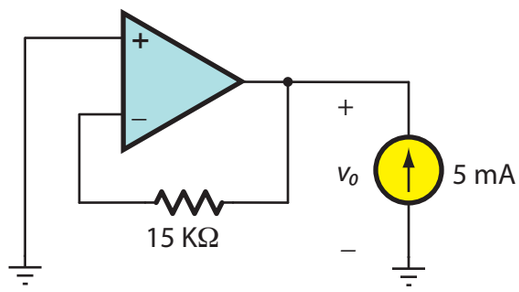
(9) During the examination a candidate must report to a supervisor before leaving the examination room.

(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.**

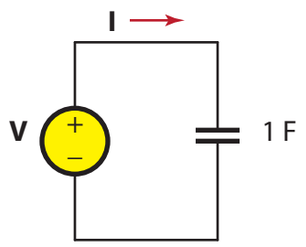
1. **[24 marks.]** Parts (a)-(h) below each have an identical weighting of three marks. Please answer the questions in the boxes provided.

(a) **[3]** In the circuit given at right, the op-amp is ideal and is operating in its linear region. Determine the output voltage v_0.



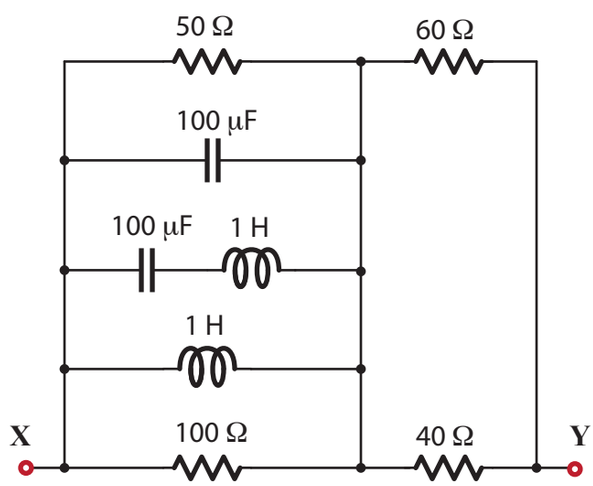
Answer: $v_0 =$

(b) **[3]** The phasor voltage source **V** in the circuit at right corresponds to $v(t) = \sin(t)$. Determine the phasor current **I**.



Answer: **I** =

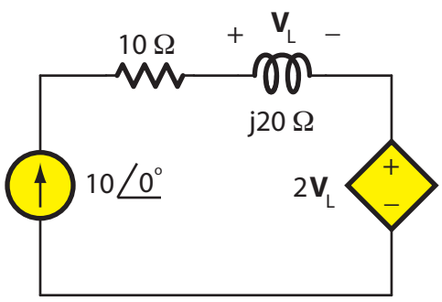
(c) **[3]** For the circuit given at right, assume that the angular frequency is $\omega = 100$ rads/sec. Determine the equivalent impedance Z_{eq} between nodes **X** and **Y**.



Answer: $Z_{eq} =$

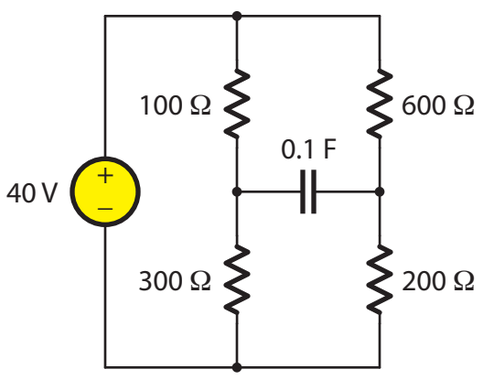
(Problem #1 continued.)

(d) **[3]** For the circuit given at right, calculate the complex power **S** (i.e., $\mathbf{P}_{comp}$) in the dependent voltage source. Specify the units for **S** in your answer.



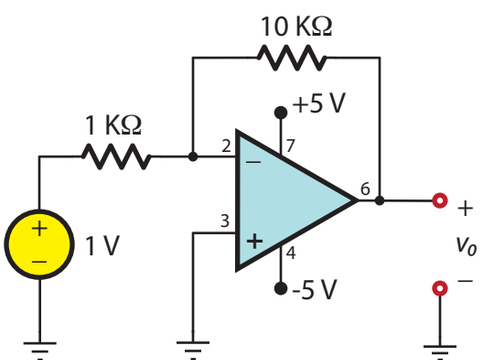
Answer: S =

(e) **[3]** In the circuit given at right, the voltage source is DC, and the circuit is in *steady state* (i.e., all voltages and currents in the circuit are constant at their correct values). Determine the energy w_C in the capacitor.



Answer: w_C **=**

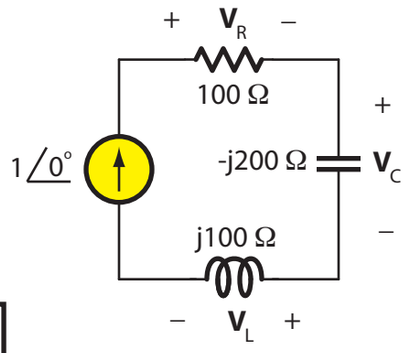
(f) **[3]** The op-amp in the circuit at right is ideal. Suppose you were to build this circuit in a similar way to the circuits in Lab #3 where a type-741 op-amp was used. After building the circuit, what output voltage v_0 would you see on the digital multimeter?



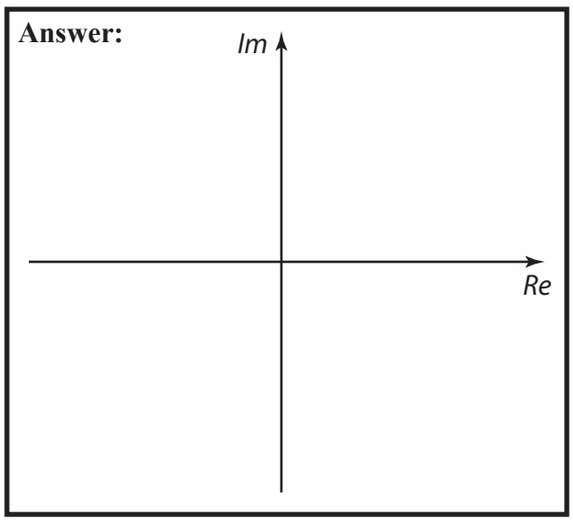
Answer: v_0 **=**

(Problem #1 continued.)

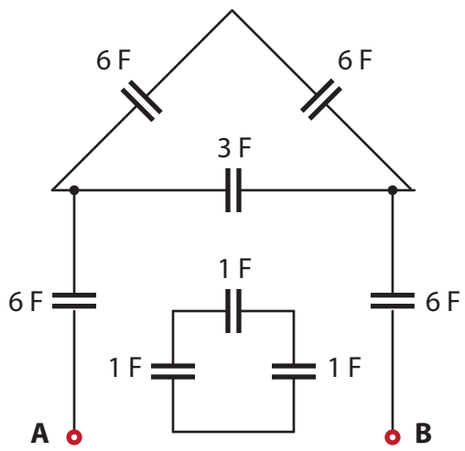
(g) **[3]** Find the phasor voltages $\mathbf{V}_R$, $\mathbf{V}_C$, and $\mathbf{V}_L$ in the circuit at right, as well as the total voltage $\mathbf{V} = \mathbf{V}_R + \mathbf{V}_C + \mathbf{V}_L$, and sketch all four phasor voltages in the diagram below. Carefully label your phasors.



Answer:



(h) **[3]** For the circuit at right, calculate the total capacitance C_{AB} between nodes **A** and **B**.



Answer: $C_{AB} =$

2. **[18 marks.]** Consider the capacitor in Fig. P2(a). The capacitor current $i_C(t)$ is shown in Fig. P2(b). For both parts (a) and (b) below, assume that there is zero initial capacitor voltage; i.e., $v_C(0) = 0$ V.

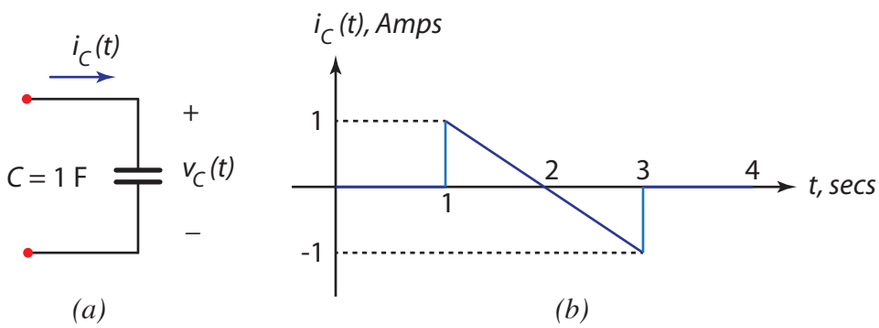


Fig. P2. Find and sketch $v_C(t)$; find power $p_C(t)$

(a) **[10]** Find and sketch the capacitor voltage $v_C(t)$ for $0 \leq t \leq 4$ seconds.

(b) **[8]** Find the capacitor power $p_C(t)$ for $0 \leq t \leq 4$ seconds (it is not necessary to sketch this).

(Problem #2 extra workspace.)

3. **[22 marks.]** The op-amps in Fig. P3 are ideal and are operating in their linear regions.

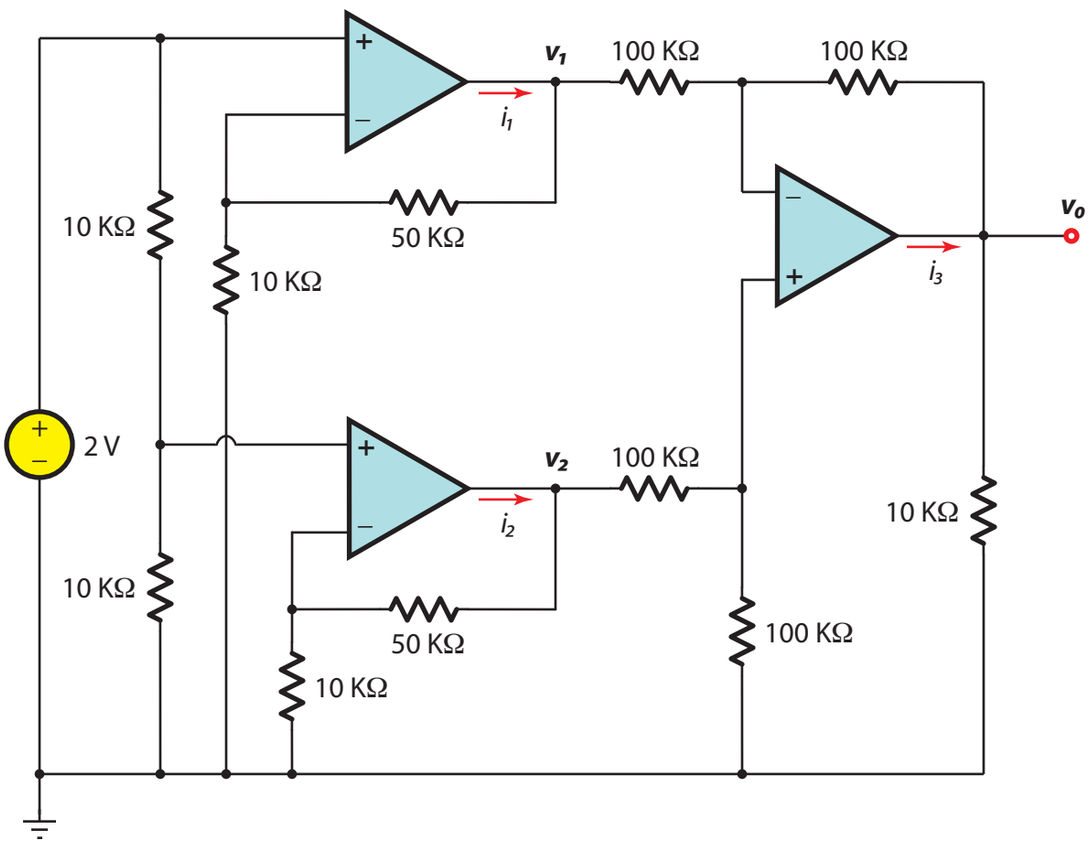


Fig. P3. Find v_1, v_2, v_0, then i_1, i_2, i_3.

(a) **[6]** Determine node voltages v_1 and v_2.

(b) **[8]** Determine the output voltage v_0.

(c) **[8]** Determine the op-amp output currents i_1, i_2, and i_3.

(Problem #3 extra workspace.)

4. **[21 marks.]** Consider the steady-state sinusoidal AC circuit in Fig. P4, which contains two sources that operate at the same frequency. Find the Thévenin and Norton equivalent circuits as seen by the impedance Z_L at the terminals **x** and **y**.

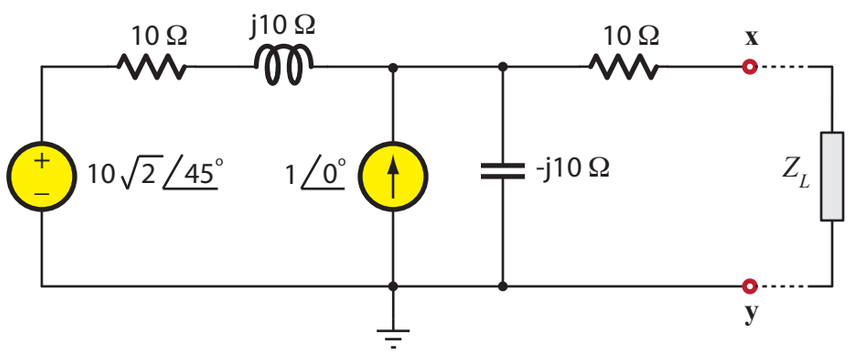


Fig. P4. Find the Thévenin and Norton equivalent circuits.

In your answers below, you may express your answers in either polar or rectangular form.

(a) **[10]** Determine the Thévenin phasor voltage $\mathbf{V}_t$.

(b) **[5]** Calculate the Thévenin impedance Z_t.

(c) **[3]** Give the Norton equivalent circuit using the Norton phasor current $\mathbf{I}_n$.

(d) **[3]** Assume that the angular frequency of the sources is $\omega = 100$ rads/sec. Calculate what two *series* circuit elements would be needed to implement the Thévenin impedance. Appropriately give an inductor value in Henrys or a capacitor value in Farads.

(Problem #4 extra workspace.)

5. **[15 marks.]** Consider a shunt-connected DC motor (i.e., the DC machine configuration in which the field windings and the armature are connected in parallel). The motor has the following full-load specifications:

   - Input voltage is $V_T = 240$ V;
   - Output power $P_{out} = 25$ HP (1 HP = 746 W);
   - Total field resistance $R_F = 50\Omega$;
   - Armature resistance $R_A = 0.138\ \Omega$;
   - Shaft speed $n_m = 1200$ rpm;
   - Efficiency $\eta = 90\%$.

   Assume that the rotational losses for this motor are negligible. The field current remains constant for both parts of this problem. Recall the basic machine equations $E_A = K\phi\omega_m$, $T_{dev} = K\phi I_A$, and $P = T\omega_m$.

   (a) **[3]** If the motor is initially powered down with $n_m = 0$, determine the armature current I_A at the moment that power is switched on to the motor.

   (b) **[6]** Find the output torque T_{out}, armature power loss P_A, field power loss P_F, and the back-emf E_A under full-load conditions.

   (c) **[6]** Say the mechanical load has changed and the new output torque is $T_{out} = 100$ Nm. Calculate the new motor speed n_m in rpm. Assume that the load torque is not affected by changes in motor speed.