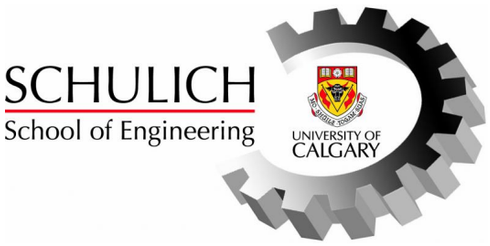
Name: _____ *Lecture Section:* _____

ID#: _____



ENGG 225 - Fundamentals of Electrical Circuits and Machines

Winter 2016 Final Examination

Wednesday, April 20, 2016
Time: 3:30 - 6:30 PM

Auxiliary Gymnasium (L01)
Red Gymnasium (L02-L04)

L01 - *Chris Macnab*
L02, L03 - *Norm Bartley*
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 *(32)*	**#2** *(18)*	**#3** *(14)*	**#4** *(18)*	**#5** *(18)*	**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.

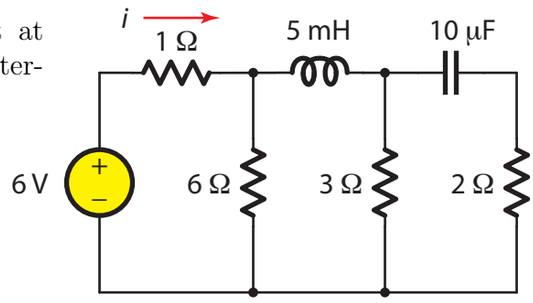
(9) During the examination a candidate must report to a supervisor before leaving the examination room.

(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.**

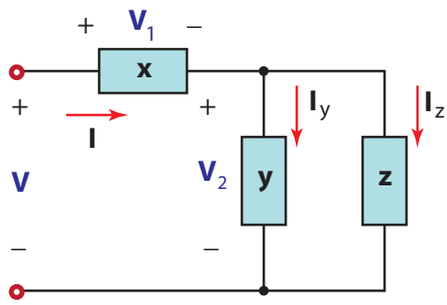
1. **[32 marks.]** Parts (a)-(h) below each have an identical weighting of four marks. Please answer the questions in the boxes provided.

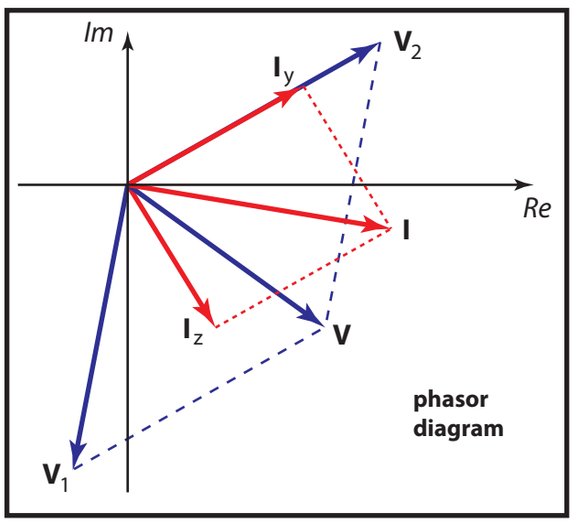
(a) **[4]** The voltage source in the circuit at right is DC and produces 6 Volts. Determine the current i.



Answer: $i =$

(b) **[4]** Consider the circuit given at right in which there are three circuit elements **x**, **y**, **z**, of unknown type. The corresponding phasor diagram is shown below. Use the information in the phasor diagram to determine what type of circuit element each of **x**, **y**, **z** must be. Choose from **R** (resistance), **L** (inductance), or **C** (capacitance) in the answer boxes below.



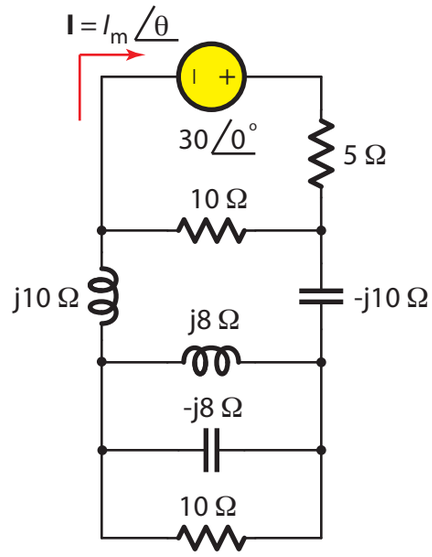


Choose: x = [R, L, or C]:

Choose: y = [R, L, or C]:

Choose: z = [R, L, or C]:

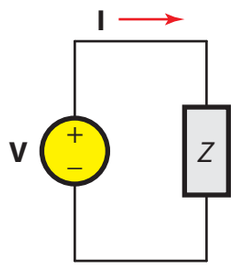
(c) **[4]** In the circuit shown at right, determine the phasor current $\mathbf{I} = I_m \angle \theta$, as shown.



Answer: $I_m =$

Answer: $\theta =$

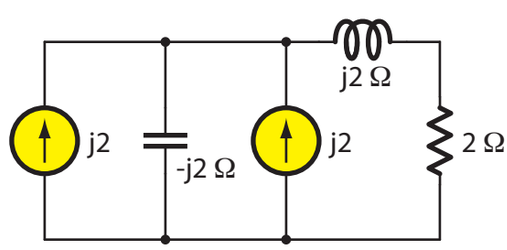
(d) **[4]** In the circuit at right, $\mathbf{V} = 6\angle 40°$ V and the complex power absorbed by the impedance Z is $\mathbf{S} = 12\angle 70°$ VA. Determine $\mathbf{I}$ and Z.



Answer: $\mathbf{I} =$

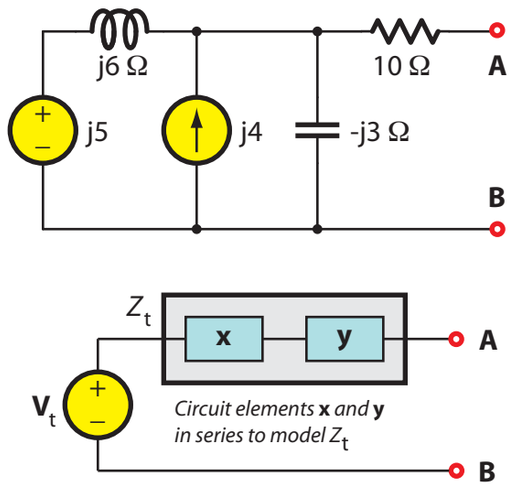
Answer: $Z =$

(e) **[4]** In the circuit given at right, use source transformations to simplify this circuit to a single voltage source and a single impedance.



(f) **[4]** Shown at right is a two-terminal circuit operating at $\omega = 2$ rads/sec. Below it is the Thévenin equivalent circuit showing a series connection of two circuit elements that may be used to model the Thévenin impedance Z_t.

Calculate just Z_t for the circuit at right, and determine what the circuit elements **x** and **y** should be to correctly model Z_t. For a resistor, give its resistance in Ohms; for an inductor, give its inductance in Henrys; for a capacitor, give its capacitance in Farads.



Answer: **x** =

Answer: **y** =

(g) **[4]** Suppose that an AC motor is operating at $P = 10$ HP (7460 W) with a power factor of 0.7 *lagging*. Sketch the power triangle with P and appropriate values for Q, apparent power $S = |\mathbf{S}|$, and the power angle θ.

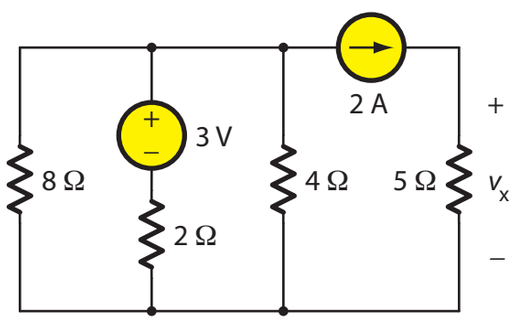
Answer: P =

Answer: Q =

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

Answer: θ =

(h) **[4]** In the circuit shown at right, calculate v_x using superposition.



Answer: v_x =

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 voltage $v_C(t)$, and the power $p_C(t)$ for $t \geq 0$ in response to the current waveform $i_C(t)$. The initial charge on the capacitor is $v_c(0) = 1.4$ V.

   (b) **[9]** For the inductor in Fig. P2(b), determine and carefully sketch the voltage $v_L(t)$, power $p_L(t)$, and energy $w_L(t)$ for $t \geq 0$ in response to the current waveform $i_L(t)$. There is no initial voltage on the inductor.

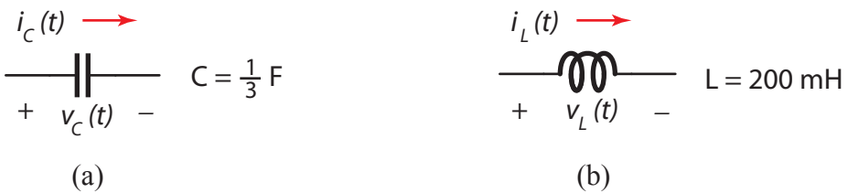
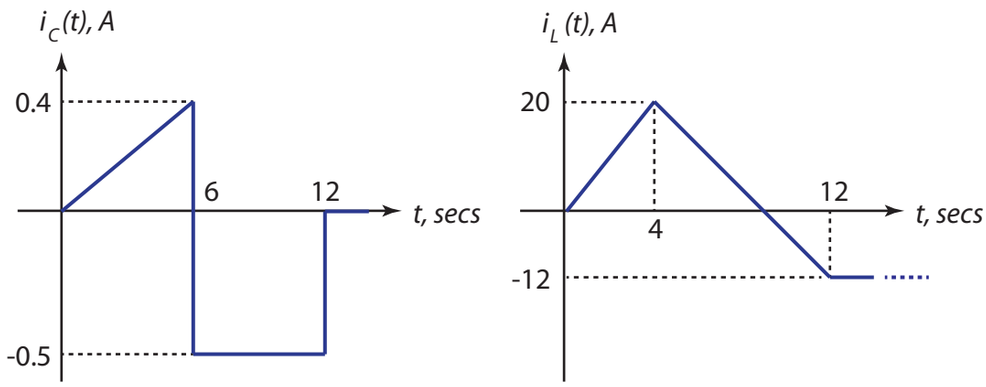


Fig. P2. In part (a), sketch $v_C(t)$ and $p_C(t)$; In part (b), sketch $v_L(t)$, $p_L(t)$, and $w_L(t)$.



(Problem #2 extra workspace.)

3. [**14 marks.**] The op-amps in Fig. P3 are ideal and are operating in their linear regions. Determine the output voltage v_o.

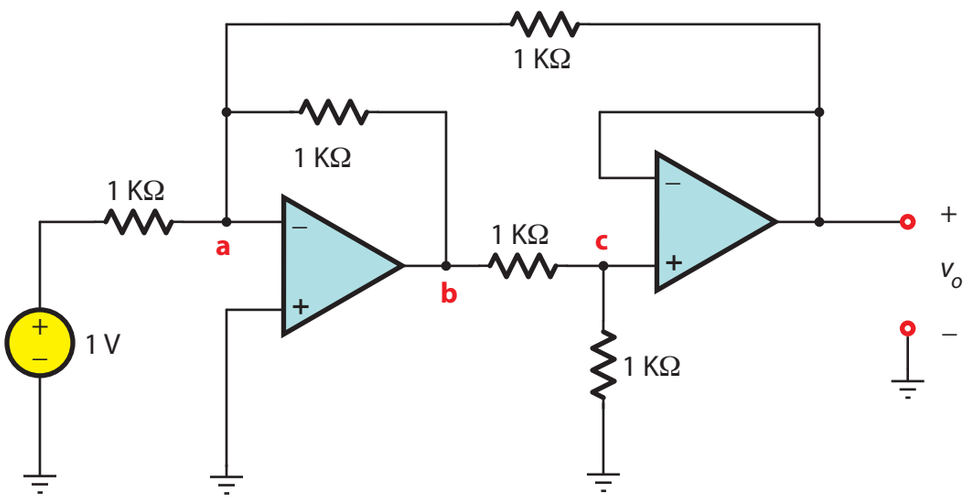


Fig. P3. Find v_o.

4. **[18 marks.]** Consider the circuit shown in Fig. P4. There are three AC sources, defined as follows:

   - $v_1(t) = 12\cos(2t)$ V.
   - $v_2(t) = 10\cos(2t)$ V.
   - $i_1(t) = 4\sin(2t)$ A.

   Find $v_0(t)$ by superposition.

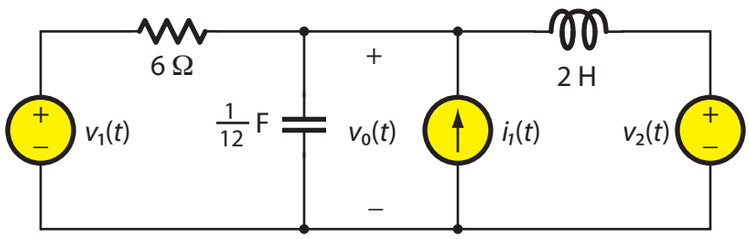


Fig. P4. Find $v_0(t)$ by superposition.

(Problem #4 extra workspace.)

5. **[18 marks.]** Consider the separately-excited DC motor shown in Fig. P5, with the steady-state full-load specifications as indicated. In parts (b) and (c) below, you may assume that the torque demanded by both the load and the rotational losses do not change with speed.

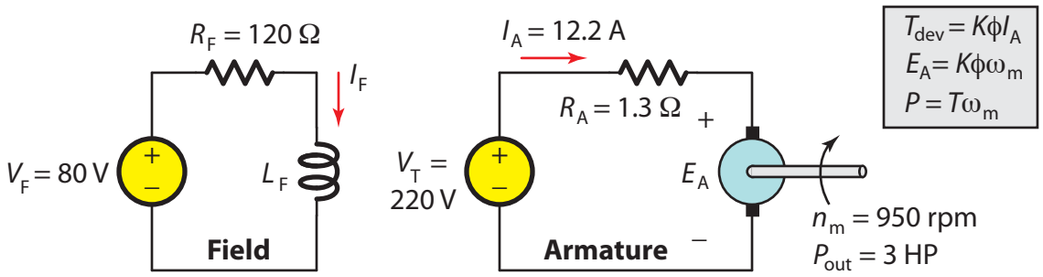


Fig. P5. Full-load specifications for a separately-excited DC motor.

Recall that $\omega_m = 2\pi n_m/60$ and 1 HP = 746 W.

(a) **[6]** Under full load conditions, find the developed power P_{dev}, developed torque T_{dev}, the armature power loss P_A, and the rotational losses P_{rot}. Give your power calculations in Watts.

(b) **[6]** Find the no-load speed of the motor in rpm.

(c) **[6]** Now suppose that the mechanical load is re-attached, and the field source voltage is reduced by half to $V_F = 40$ V. Assuming that the machine constant $K\phi$ is proportional to the field current I_F, determine the new output power P_{out} in HP.