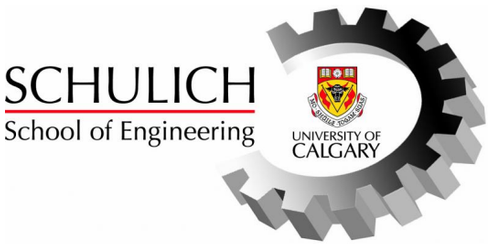
*Name:* _____ *Lecture Section:* _____

*ID#:* _____




# ENGG 225 - Fundamentals of Electrical Circuits and Machines

## Final Examination

Thursday, April 17, 2014
Time: 8:00 - 11:00 AM

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

**L01** - *Billy Wu*
**L02** - *Norm Bartley*
**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.

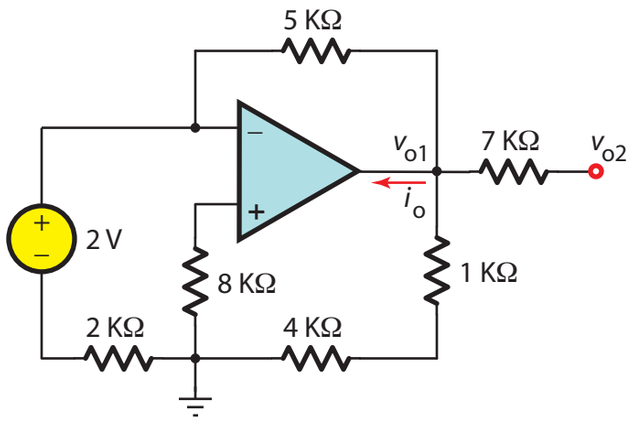
(9) During the examination a candidate must report to a supervisor before leaving the examination room.

(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]** In the circuit given at right, the op-amp is ideal and is operating in its linear region. Determine $v_{o1}$, $v_{o2}$, and $i_o$.

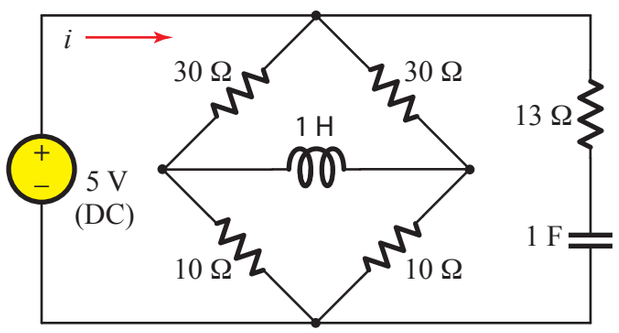



**Answer:** $v_{o1} =$

**Answer:** $v_{o2} =$

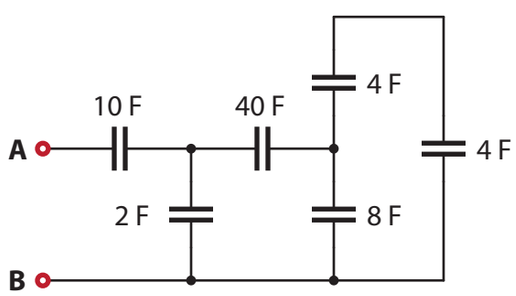
**Answer:** $i_o =$

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




**Answer:** $i =$

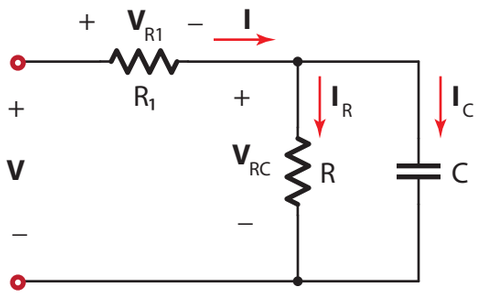
(c) **[3]** For the circuit given at right, determine the total equivalent capacitance $C_{eq}$ between terminals **A** and **B**.



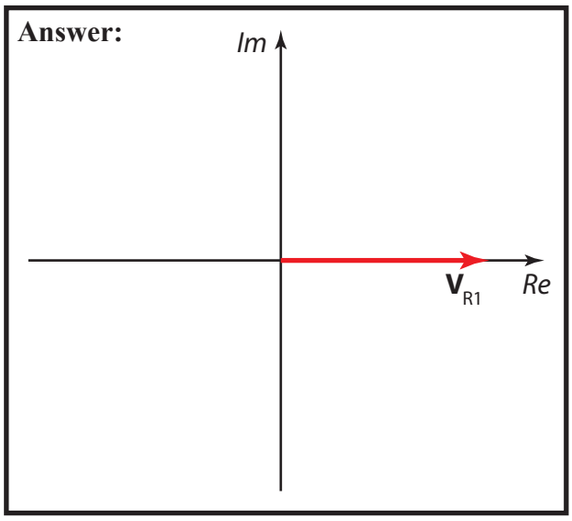

**Answer:** $C_{eq} =$

*(Problem #1 continued.)*

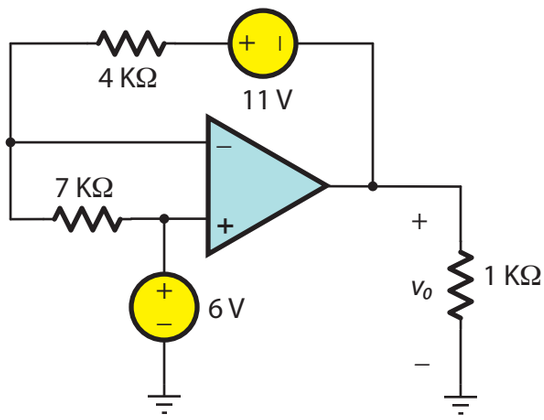
(d) **[3]** In the circuit given at right, we are given that $|\mathbf{I}_R| = |\mathbf{I}_C|$. In the space provided below, sketch the phasor diagram indicating *just the phase relationship* between $\mathbf{I}_R$, $\mathbf{I}_C$, $\mathbf{I}$, and $\mathbf{V}_{R1}$ (their magnitudes are not important). Use $\mathbf{V}_{R1}$ as the reference vector, as shown.




**Answer:**



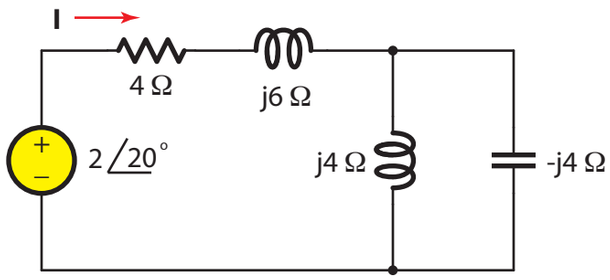

(e) **[3]** In the circuit given at right, the op-amp is ideal and is operating in its linear region. Determine $v_o$.




**Answer:** $v_o =$

*(Problem #1 continued.)*

(f) **[3]** In the circuit given at right, determine the phasor current **I**.




**Answer: I =**

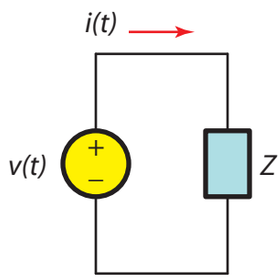
(g) **[3]** A load connected to an AC source has a power factor (PF) of 0.6 *leading*, and the average power is $P = 100$ W. Sketch the power triangle, and determine the apparent power $P_{app}$.

**Answer:** $P_{app} =$

(h) **[3]** Assume the load $Z$ in the circuit at right consists of no more than two circuit elements, and that:

$$v(t) = 10\cos(100\pi t - 20^\circ)$$
$$i(t) = 2\cos(100\pi t - 30^\circ).$$

Determine what the circuit elements are, and give their values. Capacitor values should be in Farads, inductor values in Henrys, and resistor values in Ohms.




**Element #1:**

**Element #2:**

2. **[18 marks.]** Consider the capacitor and inductor in Fig. P2(a). They both have the same current $i(t)$, which is graphed in Fig. P2(b). The initial voltage on the capacitor is $v_c(0) = -1$ V.

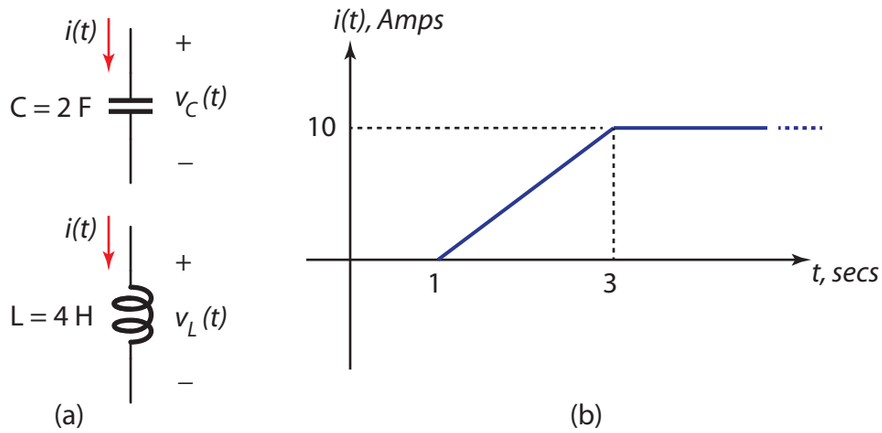



*Fig. P2. Find and sketch $v_C(t)$, $v_L(t)$; find power $p_C(t)$, $p_L(t)$*

(a) **[10]** Find and sketch the voltages $v_C(t)$ and $v_L(t)$ for $t \geq 0$.

(b) **[8]** Find the power $p_C(t)$ in the capacitor and $p_L(t)$ in the inductor for $t \geq 0$ (it is not necessary to sketch these).

*(Problem #2 extra workspace.)*

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

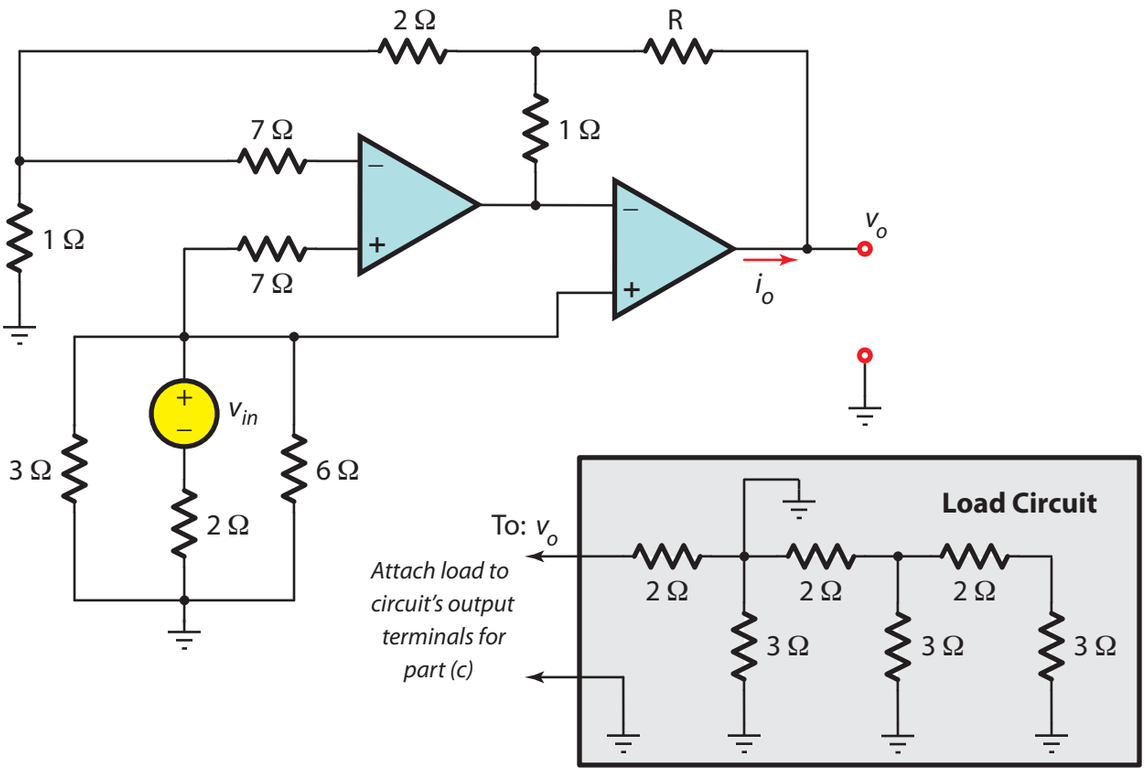



*Fig. P3. Find $v_o$ and $i_o$ with and without the load attached.*

(a) **[13]** With the load circuit disconnected at $v_o$, determine the no-load output voltage $v_o$ in terms $v_{in}$ and the unknown resistance $R$. *(You may use whatever answer you obtain here to help answer parts (b) and (c).)*

(b) **[5]** With the load still disconnected, let $v_{in} = 6$ V and $R = 1\ \Omega$. Determine $v_o$ and $i_o$.

(c) **[4]** Using the same values of $v_{in} = 6$ V and $R = 1\ \Omega$, connect the electrical load at $v_o$, and then recalculate $v_o$ and $i_o$.

*(Problem #3 extra workspace.)*

4. **[21 marks.]** Consider the steady-state sinusoidal AC analysis of the circuit in Fig. P4, where both sources operate at $\omega = 1000$ rads/s.

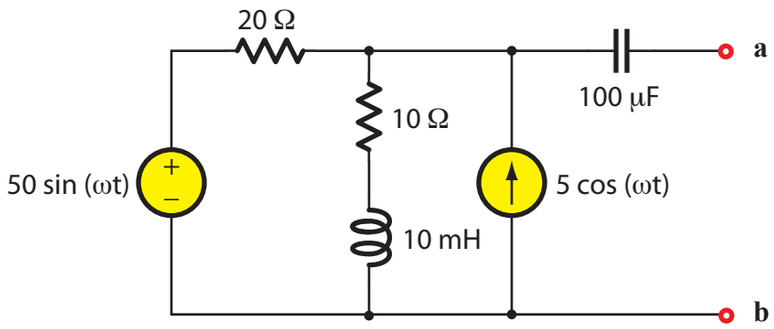



*Fig. P4. Find the Thévenin equivalent circuit.*

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

(a) **[2]** Find the complex impedances of the inductor and capacitor.

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

(c) **[5]** Calculate the Thévenin impedance $Z_t$ in Ohms.

(d) **[4]** Assume $\mathbf{V}_t = 50\sqrt{2}\angle 45^\circ$ and $Z_t = 10 + j15\ \Omega$ for this circuit. A load resistor of $R_L = 10\ \Omega$ is connected across terminals **a** and **b**. Find the average power and reactive power absorbed by the load.

*(Problem #4 extra workspace.)*

5. [**15 marks.**] Consider the separately-excited DC motor shown in Fig. P5, with the full-load specifications as indicated.

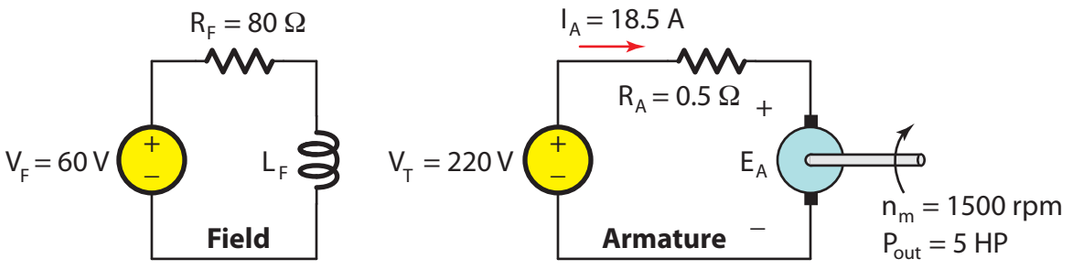



*Fig. P5. Separately-excited DC motor configuration.*

The same field circuit is used for both parts of this problem, where the total field resistance $R_F = 80\ \Omega$. 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) [**7**] Find the developed torque $T_{dev}$, armature power loss $P_A$, field power loss $P_F$, the rotational losses in Watts, and efficiency $\eta$.

(b) [**6**] Assuming that the rotational torque losses are independent of motor speed, determine the no-load speed of this motor.

(c) [**2**] Determine the developed torque $T_{dev}$ when power is first applied to the motor with $n_m = 0$ rpm.