ECE 207 Elements of Electrical Engineering II

Final Exam

Name________________________

Campus Mail__________

For full credit: 1)work neatly, 2)give appropriate units on answers, and 3)clearly show all your work.

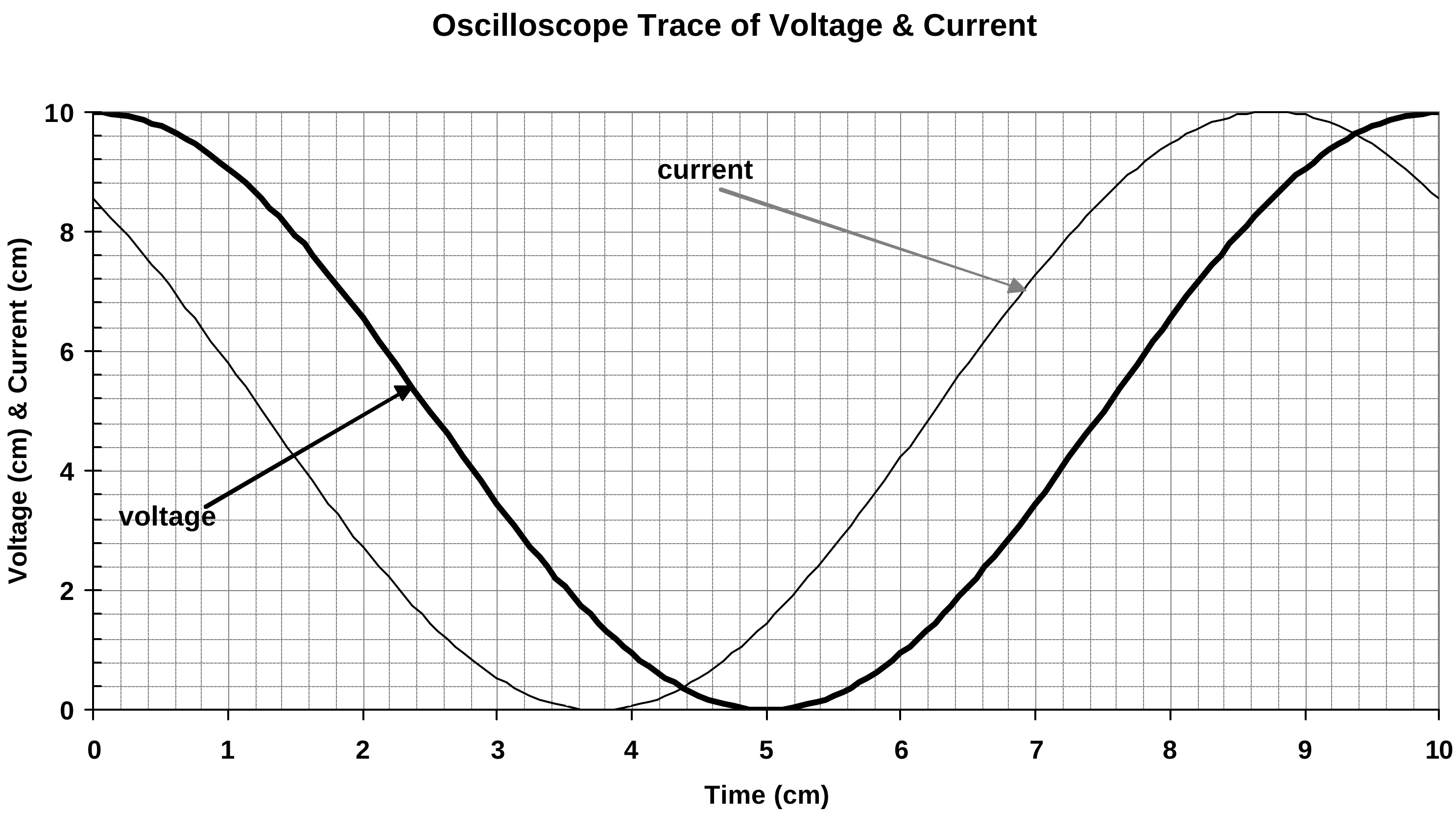
Laptops and two 2-sided 8½"x11" sheets permitted.

1 hp = 746 W, $\mu_o = 4\pi(10^{-7})$ H/m

question	possible points	awarded points
1	25	
2	25	
3	25	
4	25	
5	25	
6	25	
7	25	
8	25	
Total	200	

1. A trace from an oscilloscope is shown below. The voltage channel was set on 10 V/cm, while the current channel was set on 2 A/cm. The time-base was set at 1 msec/cm. Determine:

    i) The phasors for voltage and current (in RMS).
    ii) Complex power associated with the circuit.
    iii) Power factor associated with the circuit (be sure to indicate lag or lead).
    iv) Frequency (Hz) of the supply.
    v) Impedance of the circuit (assume elements are in series).



2. A 1ϕ transformer is rated 500 kVA, 7200 V : 600 V and has the following approximate equivalent circuit parameters referred to the high voltage side:

$$R = 2.5\,\Omega, \qquad X = 5\,\Omega, \qquad R_c = 4000\,\Omega, \qquad X_m = 3000\,\Omega$$

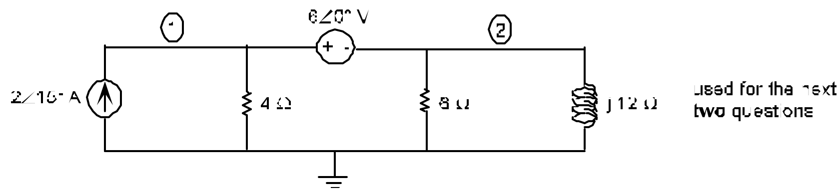
Determine the Voltage Regulation and Efficiency when rated load is supplied at 600V and 0.8 **leading** pf.

3. A three-phase, 60 Hz, Y-connected source is connected to a Y-connected load through a three-phase feeder. The three-phase load draws 900 kW at a 0.8 lagging power factor. The feeder has an impedance of 0.5 + j1.5 O/phase. The voltage at the load is 13.8 kV. Determine:

   i) *Phase a* line and phase voltages at the load (use $\mathbf{V_{an}}$ at the load as reference)
   ii) *Phase a* line and phase currents (use $\mathbf{V_{an}}$ at the load as reference)
   iii) Three-phase average power delivered by the source
   iv) Capacitance (μF/phase) of a capacitor to improve the power factor to unity at the load
   v) The magnitude of new line current after the power factor correction

4. Mark ***each*** true/false question either **T** OR **F** (2 pts each)

___ Given a circuit with 7 nodes and 2 voltage sources, the number of KCL equations necessary when performing nodal analysis will be 5.



___ The nodal equations are $\frac{\tilde{V}_1}{4\Omega} + \frac{\tilde{V}_2}{6\Omega} + \frac{\tilde{V}_2}{j12\Omega} = 2\angle 15°\ A$ **and** $\tilde{V}_1 - \tilde{V}_2 = 6\angle 0°\ V$

___ The average power *delivered* by the voltage source is $\text{Re}\left[\left(6\angle 0°\ V\right)\left(\frac{\tilde{V}_1}{4\Omega} - 2\angle 15°\ A\right)\right]$

Why or why not? ____

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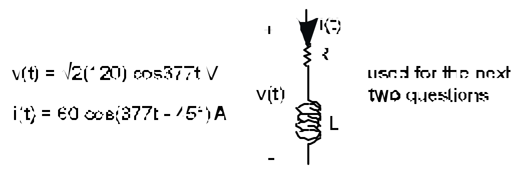


___ R = 2 Ω **and** L = 2/377 H.

___ The power absorbed is P = 3.6 kW and the power factor is $\frac{1}{\sqrt{2}}$ lagging.

Why or why not? ____

____

___ Given two loads, both with lagging power factors: the one with the lowest pf requires a pf correction capacitor with a larger value in Farads to correct the power factor to 1.

___ In a balanced 3ϕ system, if $\tilde{V}_{ab} = 120\angle 30°$ V **and** $\tilde{I}_a = 4\angle 0°$ A , then the pf=1 **and** $P_{3\phi} = \sqrt{3}(120)(4)$W.

___ Given two induction motors, both with the same rated speeds and efficiencies: Motor 1 is rated 480V, 10A. Motor 2 is rated 240V, 20A. Motor 1 and motor 2 have the same rated output power and the same rated torques.

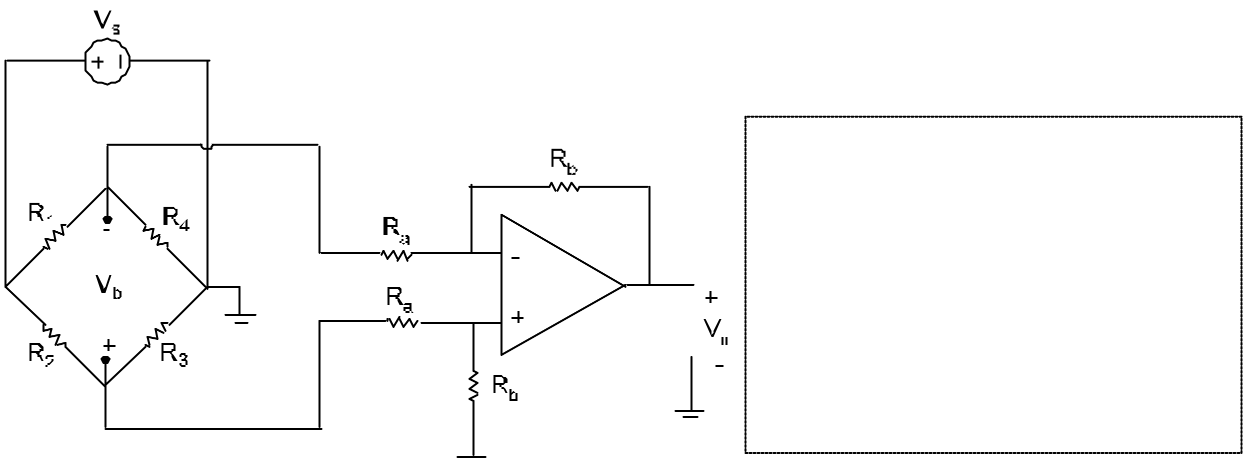
___ The rated speed of an induction motor is 3480 rpm. Assuming a 60Hz power system, this motor must be a 2-pole motor and if connected to a load requiring ¼ its rated torque, the speed of the motor-load combination will be 3510 rpm.

___ A low-pass filter with w_b = 1000 r/s and a DC gain of 10 has a transfer function of $\frac{10}{s + 1000}$ and its time-domain response to an input of 1u(t) V is $10\left(1 - e^{-t/1000}\right)$ V .

5. i) When a given load is placed on a **four-active arm** cantilever load cell, ε=0.0002. S=2, V_s=15V, R_1, R_2, R_3, and R_4 are 350Ω strain gages. Use R_a = 1 kΩ

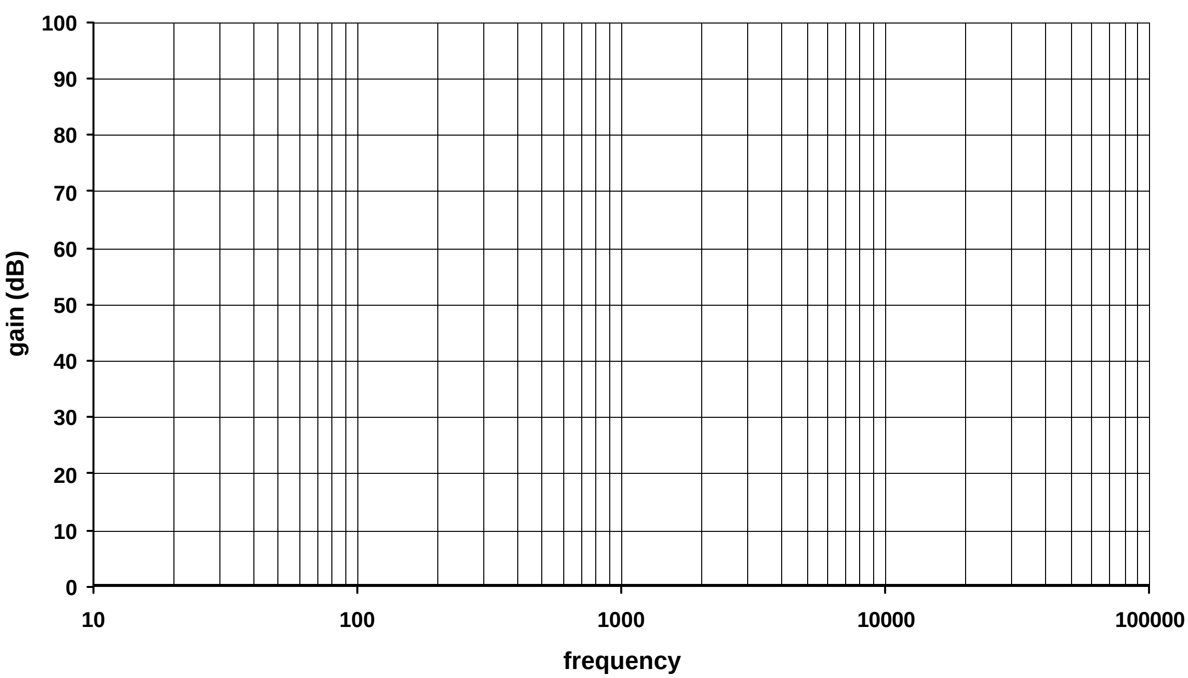
   a. What is V_b?

   b. Specify the amplifier below to give an output of V_0=60 mV for these conditions.



ii) A filtering stage is needed. Design an active ***lowpass*** filtering stage to filter V_0 with ω_b=1000 r/s and a gain of 20dB. **Use C = 0.01mF** *Neatly add this stage to the above schematic.*

iii) Neatly sketch the straight line Bode magnitude plot for $|V_{out\text{-}bp\ filter}/V_b|$



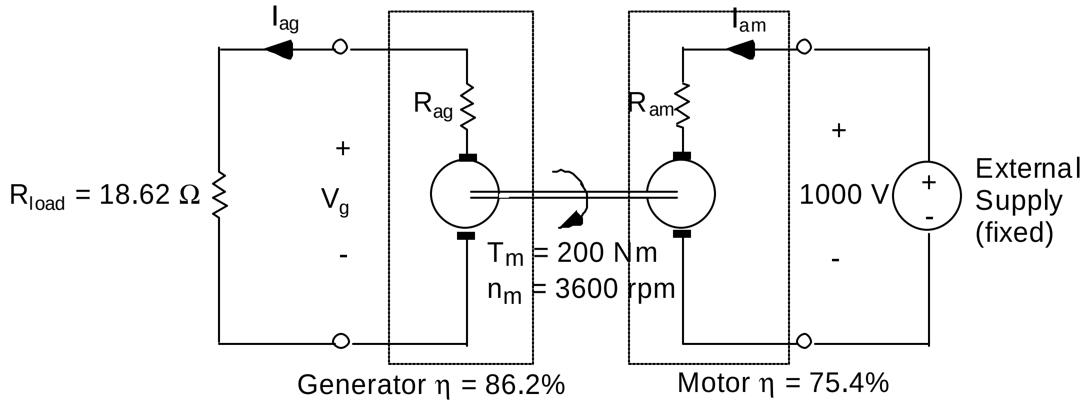
6. The system below consists of a separately excited DC motor-generator set. The field windings are

not shown. Determine:

i) the current at the motor input, I_{am}

ii) the power delivered to R_{load}

iii) the load voltage V_g

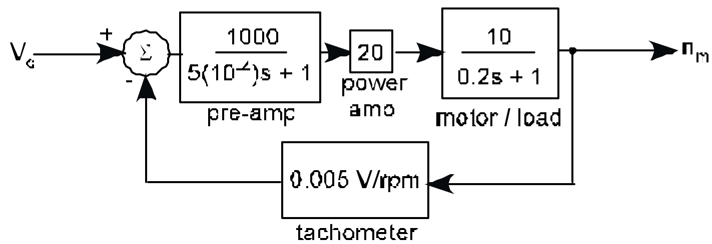


iv) Suppose the motor field current was increased (generator field current and R_{load} remains constant). Explain (in words) what affect would this have on each of the following:

- the shaft speed, n_m
- the power delivered to R_{load}
- the shaft torque, T_m
- the motor input current, I_{am}

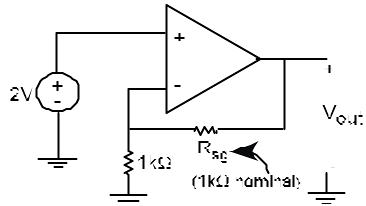
7. For the shown DC motor speed control system, determine:

   i) The ideal closed-loop gain
   ii) The exact closed-loop gain in polynomial form
   iii) Compare the steady-state values of parts i) and ii) by calculating the % Error (use the ideal value as your reference)



8. Mark ***each*** true/false question either **T** OR **F** (2 pts each)

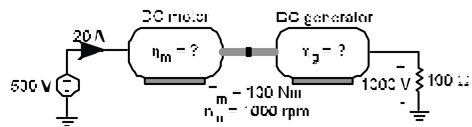
___ The advantage of RTDs is that they can reliably measure higher temperatures than any type of thermocouple.



used for the next **two** questions

___ An ideal op-amp is used to measure strain as shown above. Given a nominal 1kΩ resistance for the strain gage, and a strain gage factor of 2, v_{out} = 4.004V if the strain, ε=0.001.

___ Given the same strain gage, v_{out} = 4 cos 10t mV if the strain, ε=0.001cos(10t).



used for the next two questions

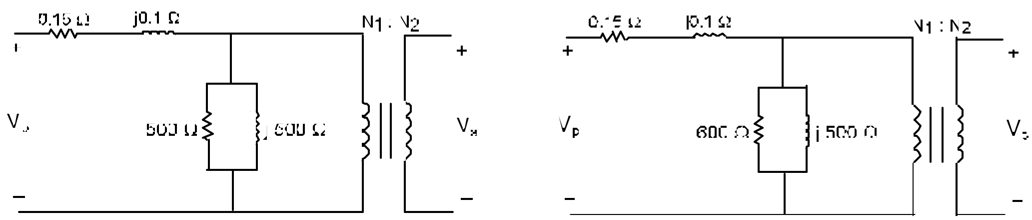
NUMERIC η_m = ______ and η_g = ______.

___ These efficiencies are not possible.

Why or why not? ____

____

___ Time and frequency domain. Lowering the break frequency of a low-pass filter will allow it, in its time-domain response to a step function input, to reach its steady-state value more quickly.



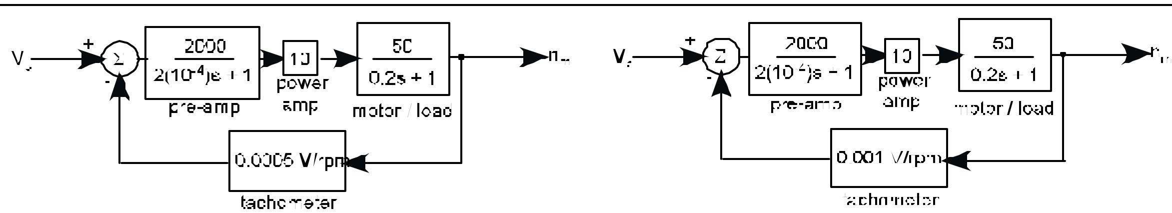
used for the next question

___ The two transformers are identical apart from different R_c. The transformer on the left will be more efficient.

Why or why not? ____

____

___ The unit step-response for a 2nd-order system is $40 - e^{-100.5t}(\cos 1000t + 0.1005\sin 1000t)$. If ζ where increased (same value of ω_n and still underdamped), the frequency of oscillations in the transient response would be lower and the transient response would die out more quickly.



used for the next two questions

___ Given identical inputs, the steady-state speed of the motor in the left system will be lower than that of the right.

___ If the motor/load transfer function in the system on the left were changed to 100/(0.2s+1), the steady-state speed of its motor/load would be doubled for a given V_c.

Why or why not? ____

____

ANSWERS

1. Note the voltage and current waveforms are given in cm with conversion factors.
   i) $\boldsymbol{V} = 35.36\angle 0°$ V, $\boldsymbol{I} = 7.07\angle 44.64°$ A, ii) $\boldsymbol{S} = 250\angle -44.64°$ VA, iii) 0.7 lead,
   iv) 100 Hz, v) $\boldsymbol{Z} = (3.56 - j3.51)\ \Omega$, [R = 3.56 Ω, C = 453.4 μF]

2. Note that, for leading pf, %VR can be negative.
   % VR = -0.825%, %η=94.2%

3. i) That is, find $\boldsymbol{V}_{ab}$ and $\boldsymbol{V}_{an'}$ at the load.
   $\boldsymbol{V}_{an'} = 7967.4\angle 0°$V, $\boldsymbol{V}_{ab} = 13800\angle 30°$V
   ii) $47.1\angle -36.9°$ A
   iii) $P_{3\phi} = 903.3$ KW
   iv) 9.4 μF
   v) 37.7 A

4. F, T, F, T, T, T, T, T, F, F

5. 6 mV, 11.75 kΩ
   ii) $R_{in} = 10$ kΩ, $R_f = 100$ kΩ
   iii) LP, break frequency at 1000 r/s, LF gain is 40 dB (20 dB from diff. amp and 20 dB from LP filter)

6. Note motor and generator efficiencies
   i) 100 A
   ii) 65 kW
   iii) 1100 V
   iv) *note that E_{am} will remain relatively constant*
      - n_m decreases which will cause generator voltage to drop
      - power to the load will therefore drop as approximately the square of the generator voltage
      - $T_g = T_m$ will be reduced because of the lower generator current
      - Since T_m is reduced even as ϕ_m is increased, I_{am} must reduce approximately quadratically

7. i) 200 rpm/V
   ii) $$\frac{200000}{10^{-4}s^2 + 0.2005s + 1001}$$
   iii) -0.1%

8. F, T, F, T, F, F, T, F, F