B.A. Mork

EE 5220 - HW #1

Transient Circuit Analysis Basics

Spring 2024
Due Jan 16th, 9am ET

The aims of this exercise are:

- Collect graded term project(s) and homeworks from all of your courses last semester, examine them for useful feedback, and use this feedback to improve your next efforts.
- Circuit analysis problems for RL and RC circuits, and one inverse LaPlace transform for an RLC response. Use this to evaluate your pre-req background and preparedness for EE5220.
- Having identified the needed review, get the needed review from past course materials, text books, office hour assistance, etc.

1) Collect any uncollected graded homeworks and term project materials from all of your courses you took last semester. Your EE5200 term project (if your took EE5200) needs to be gathered via Canvas. Identify things you could improve upon next time. Logistics, anticipation, planning ahead, technical writing, mathematical development, implementation, formatting, equation editors, IEEE format, SI unit abbreviations, etc.
   - Identify with a bulleted list the things that could be done better.
   - Write a summary paragraph as a basic plan of how to better approach the term project in this course.

   NOTE: Monday Jan 15th is a holiday.

2) Find our At-a-Glance and Canvas web pages, and add these to your Favorites.

   https://pages.mtu.edu/~bamork/ee5220/
   https://mtu.instructure.com/courses/1487599

3) Find the Homework Submission/Cover Sheet. Follow the guidance for all homework submissions. https://pages.mtu.edu/~bamork/ee5220/HMWKSUBM.pdf

4) Following the guidance of the homework submission sheet, do textbook problems 1.2, 1.3, 2.2, 2.3, 2.7.

Resources available:

- EERC 123 - Learning center coaches are available to assist with undergraduate level course concepts. Online hours are available through this Zoom link: https://www.mtu.edu/ece/undergraduate/advising/learning-center/

- EE5200 pre-req review provides 6 video lectures with notes for review of basic circuit analysis concepts. For the most part, these address phasor analysis. However, the important concepts of active and passive sign convention and double-subscript notations are covered:
  https://mtu.instructure.com/courses/1487599/modules

- Office hour requests, help sessions, etc, may be arranged if requested.

NOTE!
All course materials, unless otherwise identified or identifiable, are the intellectual property of your professor or the university. Uploading to web sites or sharing or sending to others is in violation of Academic Integrity.

Here the current is not directly proportional to the voltage, though this condition may be approximated over limited ranges. The application of superposition must be restricted to these ranges. Nonlinear resistors are used from time to time, especially as protective devices. Again, the principle of superposition should not be applied where these are located. Finally, any type of rectifier is an extremely nonlinear device since it presents almost zero impedance to the flow of current in one direction, but an almost infinite impedance to current flow in the other direction. Superposition cannot be applied indiscriminately, although it will be shown that, with care, it can be used over certain intervals, even in circuits containing rectifiers.

PROBLEMS

1.1

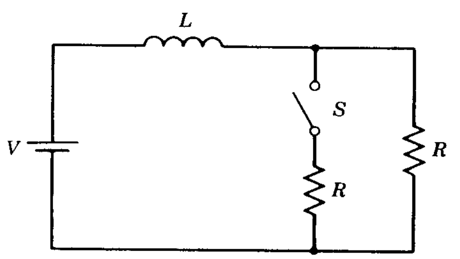


Fig. 1P.1.

The current in Fig. 1P.1 has already reached a steady value when S is closed. Derive an expression for the current through L after the closing of S.

1.2 If $V = 500$ V, $L = 20$ mH and $R = 30\ \Omega$, calculate the voltage across the inductance 1 ms after the switch S is closed in Fig. 1P.1.

1.3

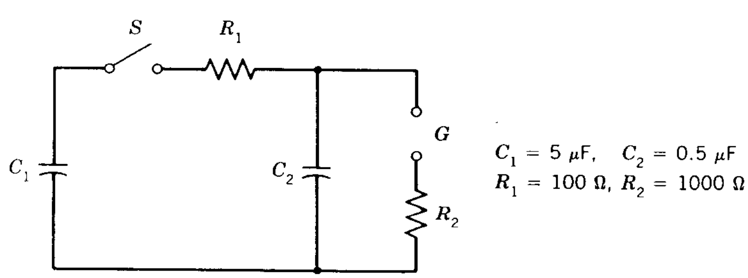


Fig. 1P.2.

Initially, the capacitor C_1 in Fig. 1P.2 is charged to 100 kV; C_2 is uncharged. The switch S is closed and 40 μs later the gap G sparks over. What is the current in R_2 and the voltage on C_1 immediately after sparkover?

1.4 How much energy has been transferred to C_2 from C_1 at the time of gap sparkover? How much has been spent in R_1?

1.5

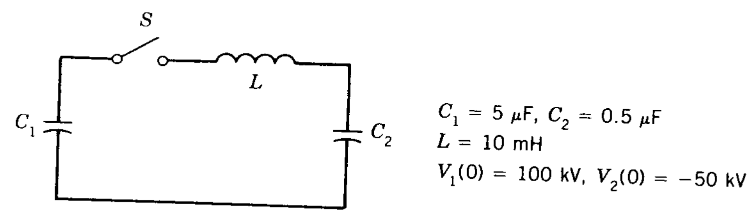


Fig. 1P.3.

What is the maximum voltage attained by C_2 and the frequency of the current that flows in L, after the switch is closed in the circuit of Fig. 1P.3?

1.6 What other natural frequency could be produced by the components of Fig. 1P.3 if they were configured differently?

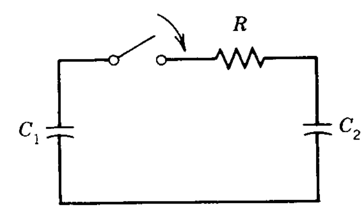
1.7 A capacitor C charged to voltage V is discharged into an inductor L. What is the voltage on C at the instant when its stored energy and that of the inductor are equal?

2.2 The transform of a certain voltage is given by:

$$\frac{1.9 \times 10^{11}}{s^2 + 2.1 \times 10^5 s + 2 \times 10^{11}}$$

Evaluate the transform and sketch its form with reasonable accuracy.

2.3 How much energy will be dissipated when the switch in the circuit in Fig. 2P.1 is closed.



$C_1 = 60\ \mu F$
$C_2 = 40\ \mu F$
$R = 5\ \Omega$

Fig. 2P.1.

The capacitor C_1 in Fig. 2P.1 has an initial charge of 1.0 C; C_2 is discharged. Calculate the following:

a. The peak current

b. The current 200 μs after the switch closes

c. The ultimate energy stored in C_2

d. The ultimate voltage on C_1

2.4 If the resistor in Problem 2.3 is replaced by an inductor with the same 60 Hz reactance, calculate the following, once the switch is closed:

a. The instantaneous current

b. The peak current

c. The energy stored in the inductance 1 ms after the switch is closed

d. The energy stored in C_1 at the same instant.

2.5 Show that if one capacitor is discharged into another through a resistor, the energy dissipated in the resistor is independent of the value of the resistor.

2.6 Each phase of a 3-phase capacitor bank is rated 60 MVA at $13.8/\sqrt{3}$ kV. A second bank has a rating of 30 MVA at $13.8/\sqrt{3}$ kV. The two are to be paralled by momentarily connecting them through a 100 Ω stainless steel resistor (one for each phase), which will be subsequently shorted out. You are to design these resistors (determine the length and cross-sectional area of the wire to be used) if the temperature rise of a resistor is not to exceed 200°C, when the switching operation is made at a time when one capacitor is at positive peak voltage and the other at negative peak voltage.

The characteristics of stainless steel are: density = 7.9 g/cm^3; specific heat = 0.5 J/g per °C; resistivity = 72 Ω cm. Assume that no heat is lost to the surroundings during the switching operation.

What will be the weight of the resisitor? What will be the peak current during the switching operation?

2.7

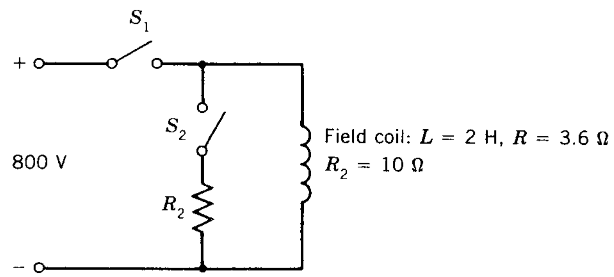


Fig. 2P.2.

Figure 2P.2 shows the field coil of a machine. It is excited by closing switch S_1 onto an 800 V d.c. bus. Determine the energy stored in the coil, and the energy already dissipated in it, 1 s after S_1 is closed.

When the coil current has attained a steady value, S_1 is opened and S_2 is closed simultaneously. What will be the voltage across S_1 0.1 s later? How much energy will eventually be dissipated in R_2?

2.8 We are often required to design test circuits which will generate surges of specific waveform. These are then used to apply surges to pieces of power equipment (transformers, generators, reactors, etc.) we wish to test. Sometimes we wish to simulate the effect of a lightning surge, sometimes a switching surge.

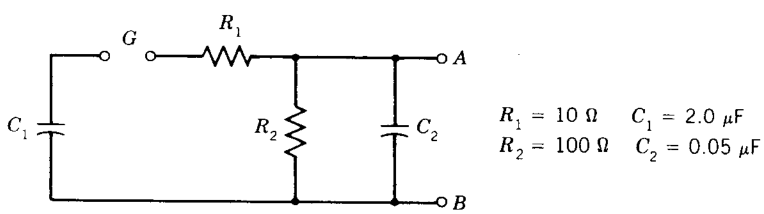


Fig. 2P.3.

Figure 2P.3 shows a basic form of impulse generator. When C_1 has been charged and the gap G is caused to spark over, an impulse voltage is generated at the output terminals A and B.

Without solving the equation of the circuit, compute a good estimate of the following when the precharge voltage is 500 kV and the gap discharges.

a. The maximum current in R_1

b. The maximum voltage across C_2

c. The time when this voltage (b) is reached

d. The output voltage after 0.5 μs

e. The output voltage after 50 μs

2.9

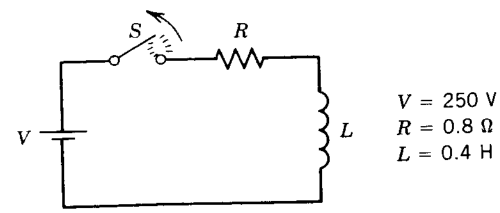


Fig. 2P.4.

R and L in Fig. 2P.4 represent the resistance and inductance of the field winding of a machine. The switch S has been closed and a steady direct current is flowing from the source V.

When S is opened, an arc is established between its contacts which develops a voltage of 400 V, opposing the flow of current. Plot the current after S opens.

REFERENCES

1. S. Goldman, *Laplace Transform Theory and Electrical Transients*, Dover Publications, New York (1966).
2. G. W. Carter, *The Simple Calculation of Electrical Transients*, Cambridge University Press, New York (1944).