
EECS 16A Designing Information Devices and Systems I Homework 9
 Fall 2022

This homework is due Friday, Nov 4, 2022 at 23:59.

Self-grades are due Monday, Nov 7, 2022 at 23:59.

Submission Format

Your homework submission should consist of **one** file.

- `hw9.pdf`: A single PDF file that contains all of your answers (any handwritten answers should be scanned).

Submit the file to the appropriate assignment on Gradescope.

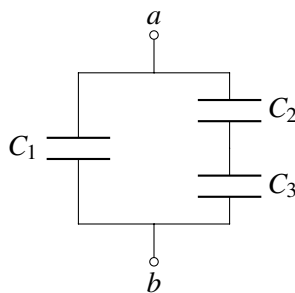
1. Reading Assignment

For this homework, please read Notes 16, 17 (17.1 - 17.2, specifically) and 17B. Note 16 will provide an introduction to capacitors (a circuit element which stores charge), capacitive equivalence, and the underlying physics behind them. Sections 17.1 - 17.2 in Note 17 will provide an overview of the capacitive touchscreen and how to measure capacitance. Note 17B will provide a walkthrough of the charge-sharing algorithm.

- Consider the capacitive touchscreen. Describe how it works, and compare and contrast it to the resistive touchscreens we have seen in previous lectures and homeworks.
- In the charge sharing algorithm, what property of charge is applied in connecting phase 1 calculations to phase 2 calculations?

2. Equivalent Capacitance (9 points)

- (4 points) Find the equivalent capacitance between terminals a and b of the following circuit in terms of the given capacitors C_1 , C_2 , and C_3 . Leave your answer in terms of the addition, subtraction, multiplication, and division operators **only**.

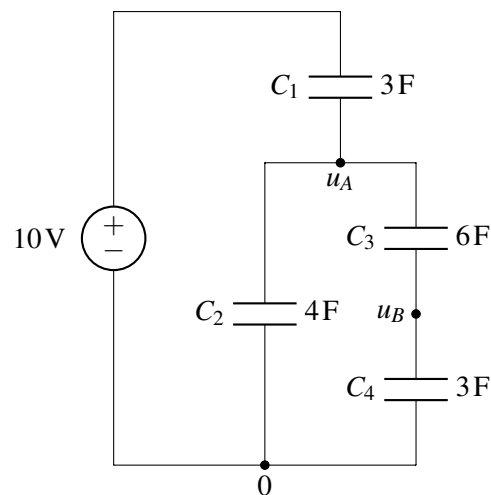


- (5 points) Find and draw a capacitive circuit using three capacitors, C_1 , C_2 , and C_3 , that has equivalent capacitance of

$$\frac{C_1(C_2 + C_3)}{C_1 + C_2 + C_3}$$

3. Circuit with Capacitors

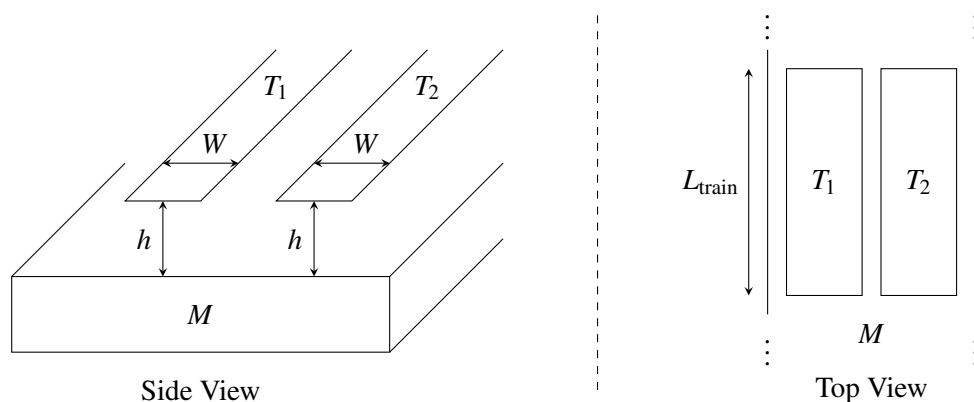
Find the voltages at nodes u_A and u_B , and currents flowing through all of the capacitors at steady state. Assume that before the voltage source is applied, the capacitors all initially have a charge of 0 Coulombs.



4. Maglev Train Height Control System

One of the fastest forms of land transportation are trains that actually travel slightly elevated from the ground using magnetic levitation (or “maglev” for short). Ensuring that the train stays at a relatively constant height above its “tracks” (the tracks in this case are what provide the force to levitate the train and propel it forward) is critical to both the safety and fuel efficiency of the train. In this problem, we’ll explore how maglev trains use capacitors to stay elevated. (Note that real maglev trains may use completely different and much more sophisticated techniques to perform this function, so if you get a contract to build such a train, you’ll probably want to do more research on the subject.)

- (a) As shown below, we put two parallel strips of metal (T_1 , T_2) along the bottom of the train and we have one solid piece of metal (M) on the ground below the train (perhaps as part of the track).

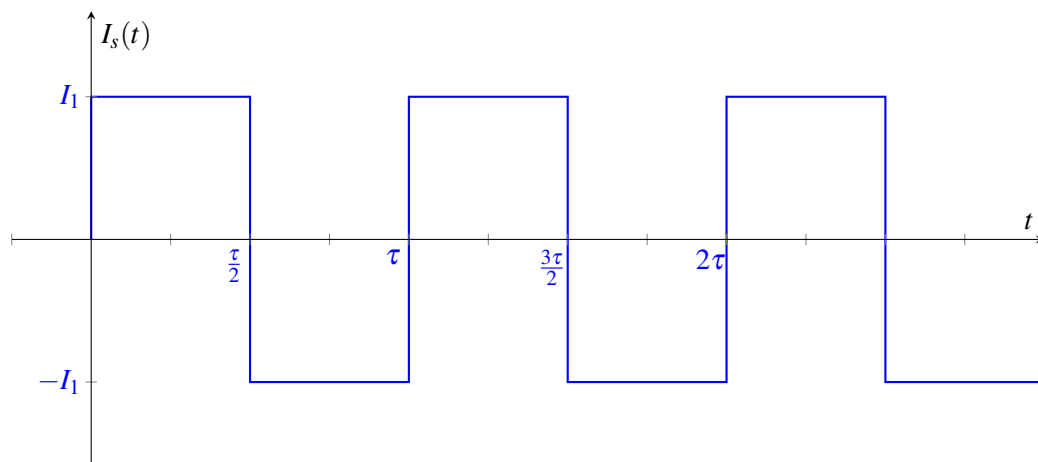
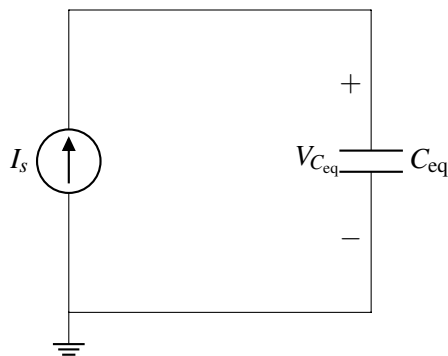


Assuming that the entire train is at a uniform height above the track and ignoring any fringing fields (i.e., we can use the simple equations developed in lecture to model the capacitance), as a function of L_{train} (the length of the train), W (the width of T_1 and T_2), and h (the height of the train off of the track), what is the capacitance between T_1 and M ? What is the capacitance between T_2 and M ?

- (b) Any circuit on the train can only make direct contact at T_1 and T_2 . Thus, you can only measure the equivalent capacitance between T_1 and T_2 . Draw a circuit model showing how the capacitors between T_1 and M and between T_2 and M are connected to each other.
- (c) Using the same parameters as in part (a), provide an expression for the equivalent capacitance between T_1 and T_2 .
- (d) We want to build a circuit that creates a voltage waveform with an amplitude that changes based on the height of the train. Your colleague recommends you start with the circuit as shown below, where I_s is a periodic current source, and C_{eq} is the equivalent capacitance between T_1 and T_2 . The graph below shows I_s , a square wave with period τ and amplitude I_1 , as a function of time.

Find an equation for and draw the voltage $V_{C_{eq}}(t)$ as a function of time. Assume the capacitor C_{eq} is discharged at time $t = 0$, so $V_{C_{eq}}(0) = 0\text{ V}$.

Hint: Your final expression should resemble a periodic function.

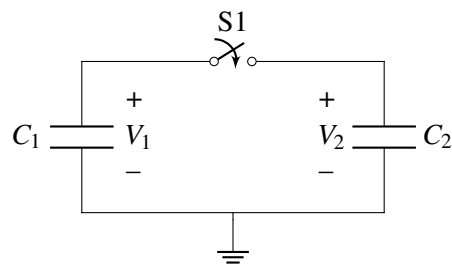


5. Charge Sharing

In the circuit below, switch S_1 is initially open. Capacitor $C_1 = 10^{-3}\text{ F}$ is initially charged to $V_1 = 3\text{ V}$ and capacitor $C_2 = 3 \times 10^{-3}\text{ F}$ is initially charged to $V_2 = 2\text{ V}$.

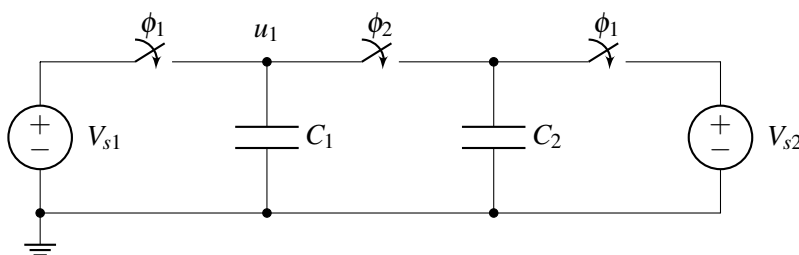
Now S_1 is closed. Calculate the new value of V_2 .

Hint: Remember that charge is conserved at floating nodes.

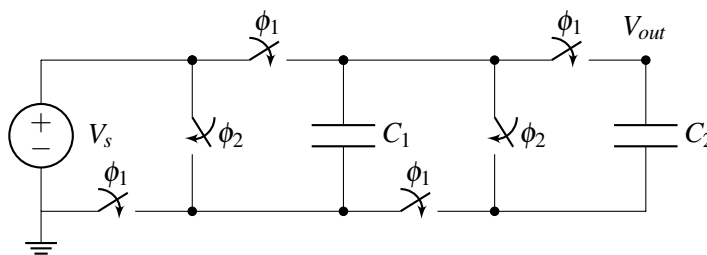


6. Capacitive Charge Sharing

Consider the circuit below with $C_1 = C_2 = 1 \mu\text{F}$ and two switches ϕ_1, ϕ_2 . Suppose that initially the switch ϕ_1 is closed and ϕ_2 is open such that C_1 and C_2 are charged through the corresponding voltage sources $V_{s1} = 1 \text{ V}$ and $V_{s2} = 2 \text{ V}$.

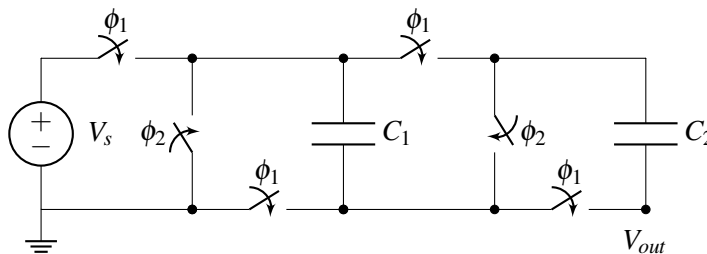


- (a) How much charge is on C_1 and C_2 ? How much energy is stored in each of the capacitors? What is the total stored energy?
- (b) Now suppose that some time later, switch ϕ_1 opens and switch ϕ_2 closes. What is the value of voltage u_1 at steady state?
- (c) Now let's look at the following circuit:



What is the value of voltage V_{out} at the end of phase 2 (steady state)? Does it depend on the values of capacitors C_1 and C_2 ? *Hint:* It may be useful to redraw the circuit during phases ϕ_1 and ϕ_2 .

- (d) A variation of the circuit from part c is shown below:



What is the value of voltage V_{out} at the end of phase 2 (steady state)? Does it depend on the values of capacitors C_1 and C_2 ? *Hint:* It may be useful to redraw the circuit during phases ϕ_1 and ϕ_2 .

7. Homework Process and Study Group

Who did you work with on this homework? List names and student ID's. (In case you met people at homework party or in office hours, you can also just describe the group.) How did you work on this homework? If you worked in your study group, explain what role each student played for the meetings this week.