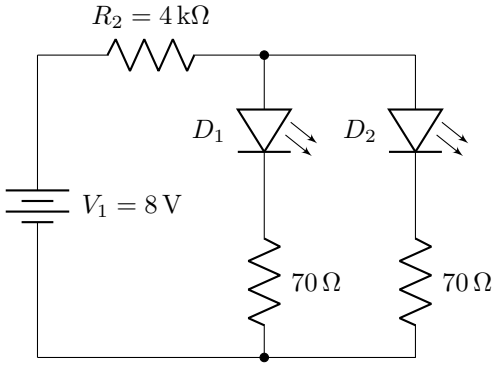
Name: _____ Lab section/TA: _____

ENGR 40M Problem Set 4

Due 1:30pm, August 4, 2017

Problem 1: More LEDs!

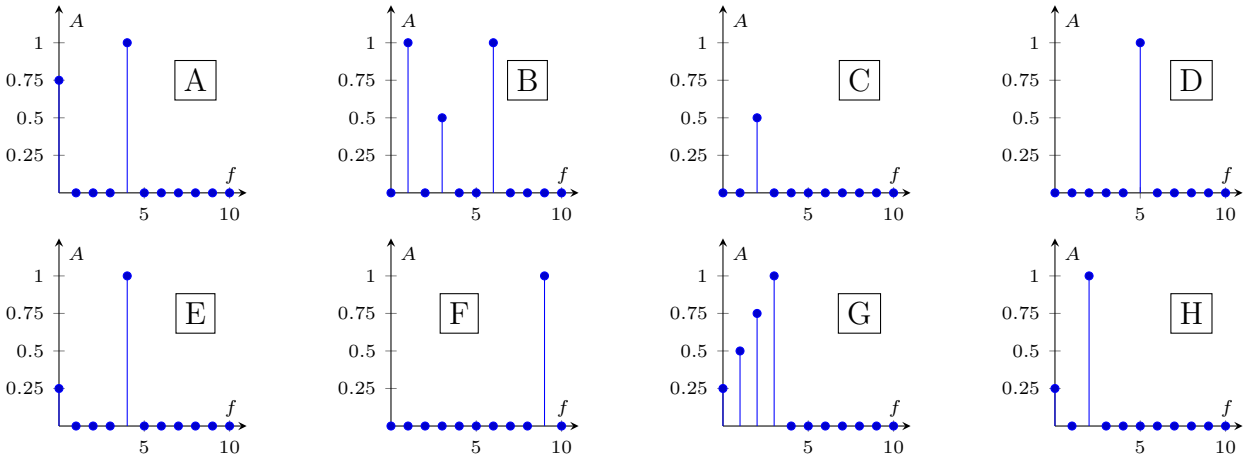
(8 points) Consider the circuit below. LED D_1 has a forward voltage of 3 V and LED D_2 has a forward voltage of 2 V. What is the current through each LED?

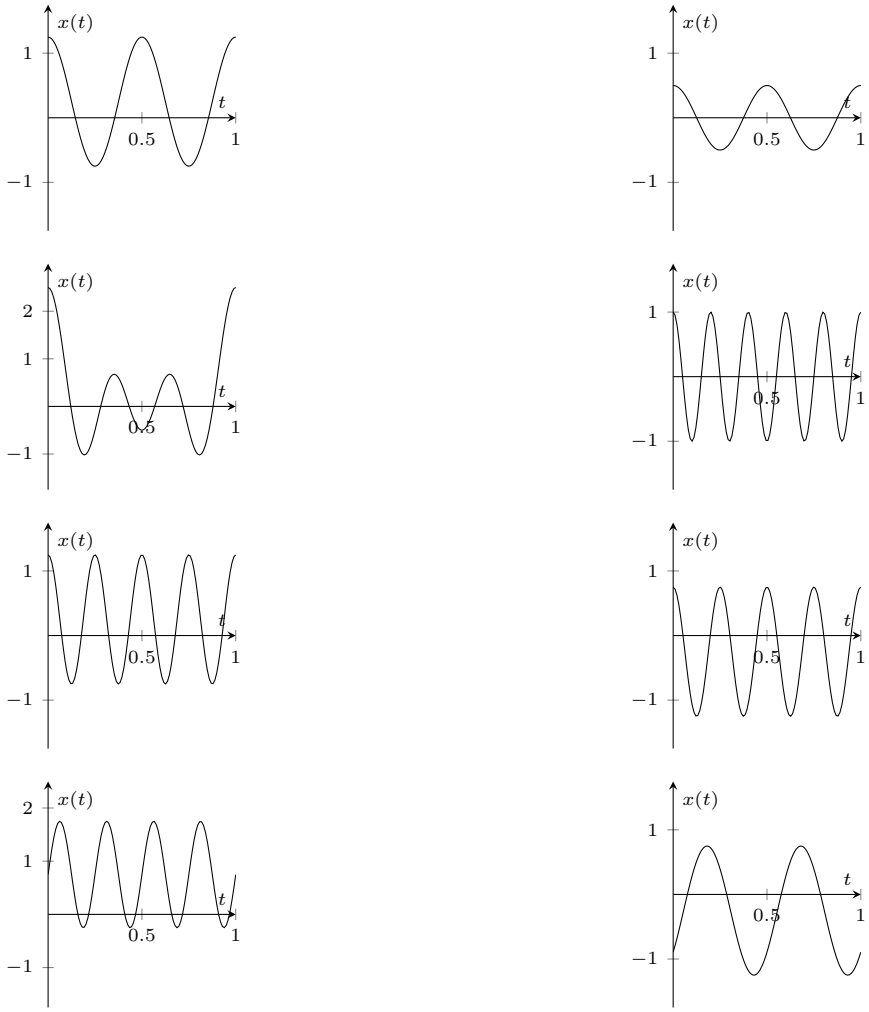


Problem 2: Fourier Transforms Fun

(8 points)

For each time domain waveform shown below, write the letter of the matching frequency domain representation and give a very brief (1 sentence or less) justification. Note that because we're only showing the amplitude and not the phase, multiple waveforms may share the same frequency representation.

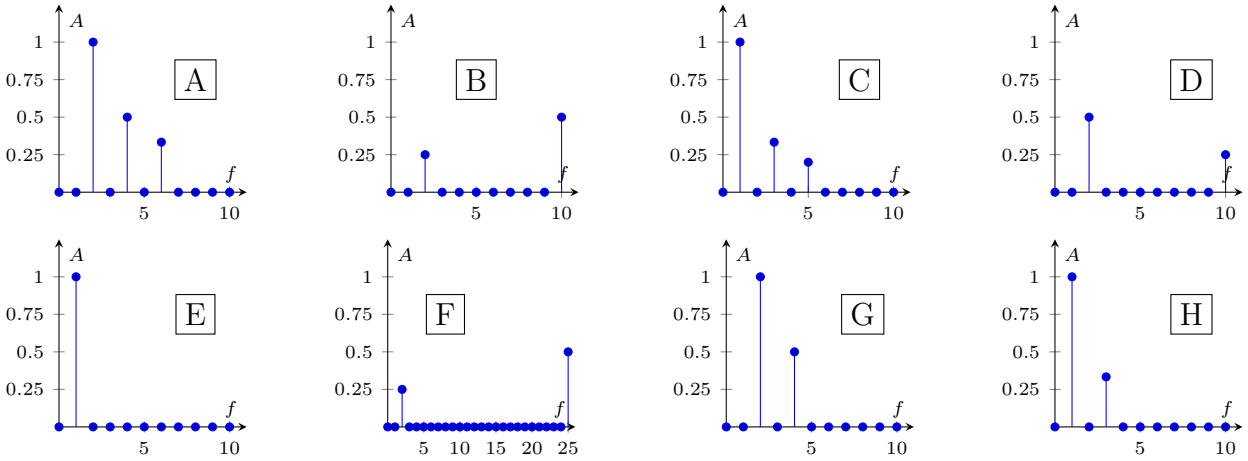


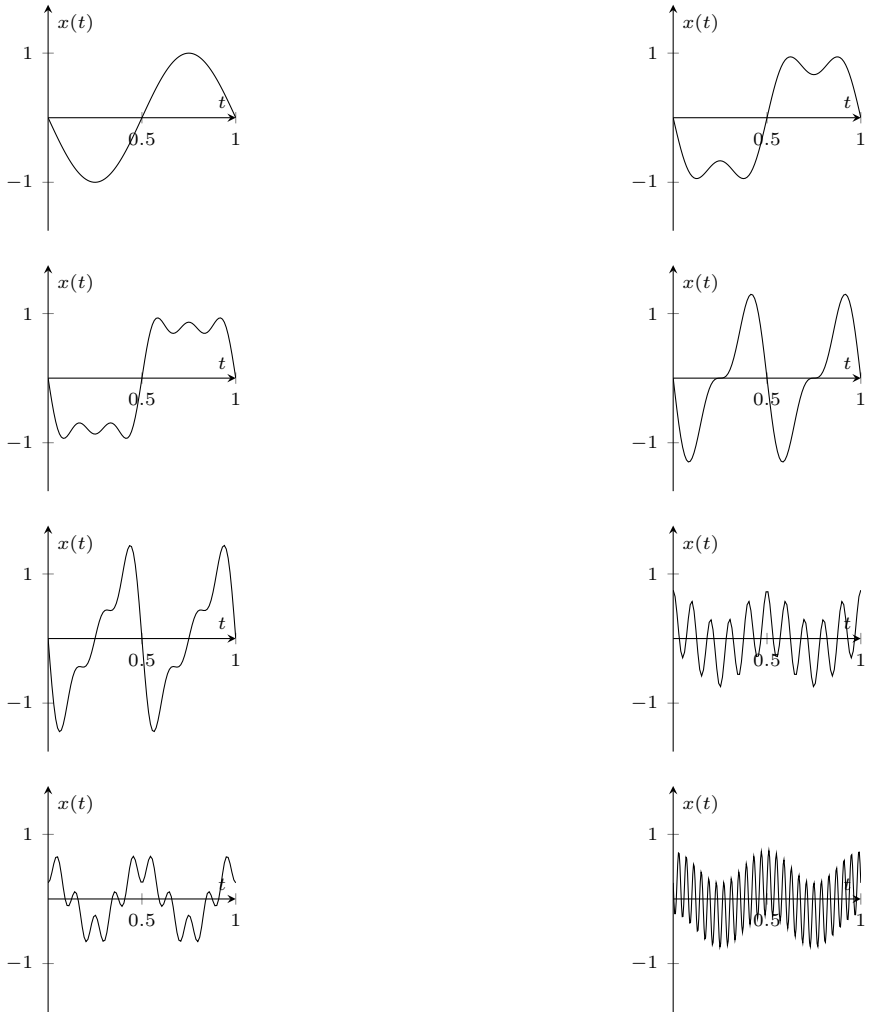


Problem 3: More Matching

(4 points)

Same as the previous problem, but these are a bit trickier.

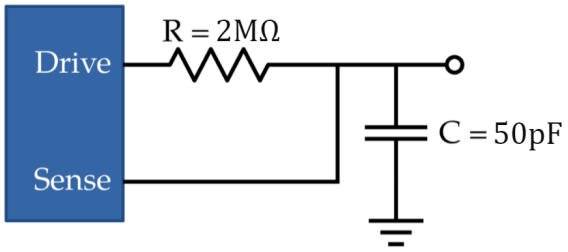




Problem 4: Capacitive sensing

(8 points) The fact that your body has capacitance is one of the principles that makes touchscreens work. In this problem, we'll explore out how to make a simple touch sensor, using only two digital pins on an Arduino.

Suppose we have the circuit below, where "drive" is a digital output and "sense" is a digital input. Instead of a regular capacitor, C can be a long wire, or even a piece of tin foil. Assuming there is no initial voltage on the capacitor, the sense pin will read a 1 when the voltage goes above 3 V.



(a) Assume there is no charge on the capacitor, and then the drive pin goes high (5 V) at time $t = 0$. At what time will the sense pin first read a 1?

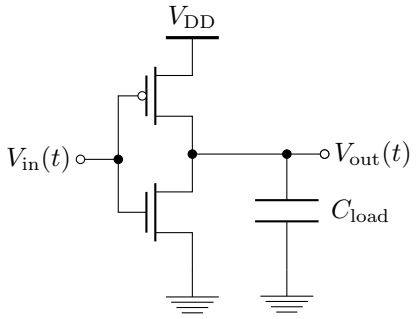
(b) Now suppose you touch the "capacitor" wire with your finger, and the capacitance goes up to 80 pF. Now how long will it take for the sense pin to read a 1?

You can read more about this at playground.arduino.cc/Main/CapSense. Some members of the teaching staff will be excited if you use this to control your LED cube.

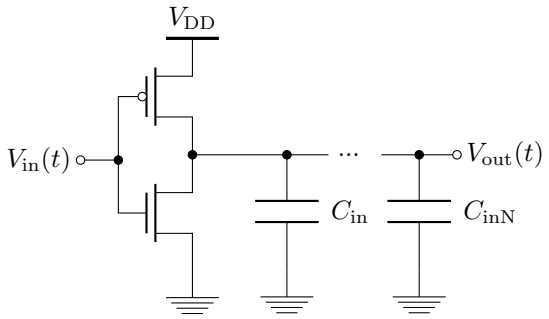
Problem 5: Logically I'm a Big Fan...Out

(4 points)

You are given that R_{on} for the PMOS and NMOS transistors are both $25\,\Omega$.



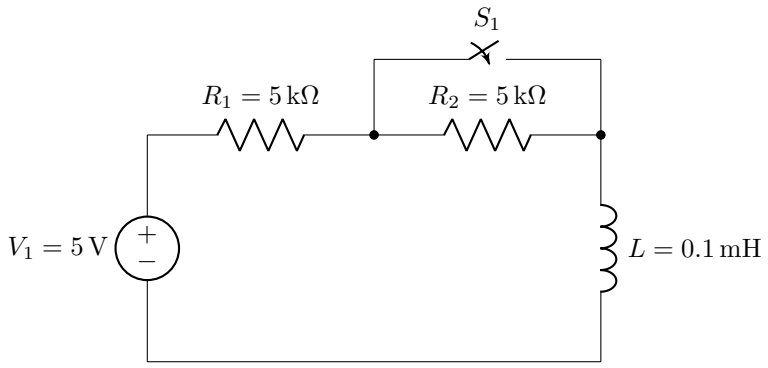
(a) Plot $V_{\text{out}}(t)$ given that $V_{\text{in}}(t)$ is a square wave that transitions between 0 and 5 V with a period of 50 ps. You are also given that $C_{\text{load}} = 100\,\text{fF}$.



(b) Assuming that connecting an inverter to the output of an inverter is equivalent to connecting a 50 fF capacitor (C_{in} in the figure above). How many inverters can be connected to the output of an inverter if the output voltage should reach 4.5 V or 0.5 V by half the 'on' time to be read as a valid 1 or 0?

Problem 6: Messing with an Inductor!

(6 points) The RL circuit depicted in the following figure has been running for an infinitely long amount of time, with switch S_1 closed.



(a) If S_1 is flicked open at $t = 0$, find the expression for the current through inductor.

(b) If S_1 is flicked closed again at $t = 10\,\text{ns}$, what is the current through the inductor right after the switch is flicked?

(c) For the case in part (b), find the expression for the current through inductor as a function of time after the switch is flicked closed.

Problem 7: Reflection

(2 points)

(a) How long did it take you to complete this assignment?

(b) Which problem was the most difficult, and why?