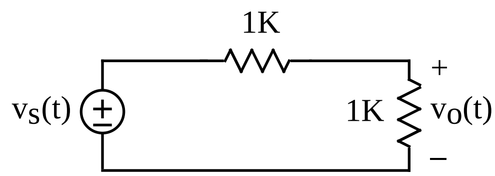
ECE 204 - THE VERY BASICS - INVESTIGATION 1
INTRODUCTION TO SWITCHING CIRCUITS - PART I

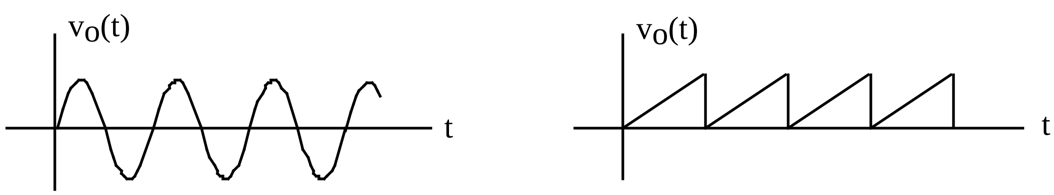
FALL 2003 **A.P. FELZER**

To do "well" on this investigation you must not only get the right answers but must also do neat, complete and concise writeups that make obvious what each problem is, how you're solving the problem and what your answer is. You also need to include drawings of all circuits as well as appropriate graphs and tables.

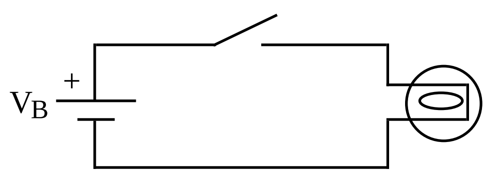
In ECE 109 we studied resistor circuits like the following



When we analyzed these circuits and when we built them in the lab we found that their voltages and currents could vary *continuously* over wide ranges of values - with all kinds of inputs and outputs like the following sinusoid and sawtooth



We refer to these kinds of circuits as **analog circuits**. In this class on **digital circuits**, on the other hand, we work with circuits like the following made from switches, lights and DC sources

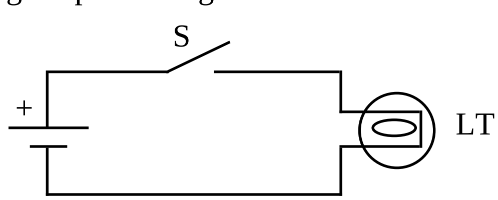


containing circuit elements that can have only one of two possible values. In particular

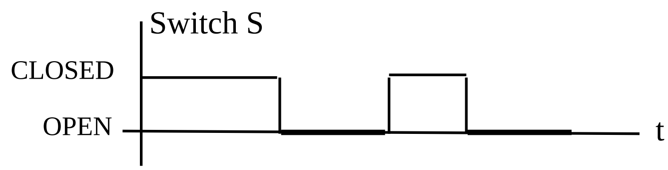
(1) The switch can be either OPEN or CLOSED
(2) And the light can be either ON or OFF

The overall goal of this class is to introduce methods for analyzing and designing digital circuits that can be used in everything from computers to traffic light controllers. The objective of this first Investigation is to introduce ways of specifying what's going on in digital circuits made from switches and lights - circuits we refer to as **switching or logic circuits**. In future Investigations we'll replace the switches with integrated circuits.

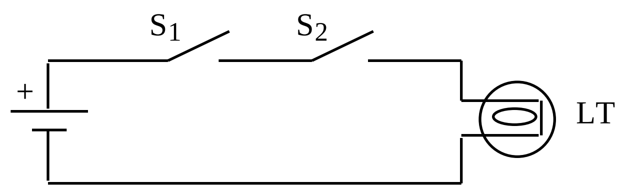
1. We begin with the following simple flashlight circuit



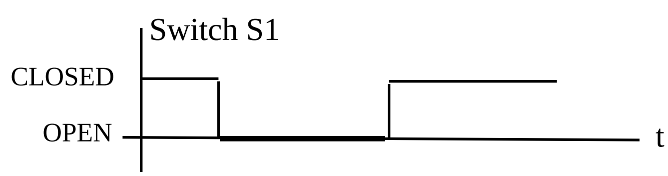
a. Complete the following sentence for the Light LT: The light LT is ON if S is . . .
b. Make use of the following graph showing when Switch S is OPEN and when CLOSED to draw the corresponding graph for when Light LT is ON and when it's OFF. Note that we refer to these graphs as **timing diagrams**.

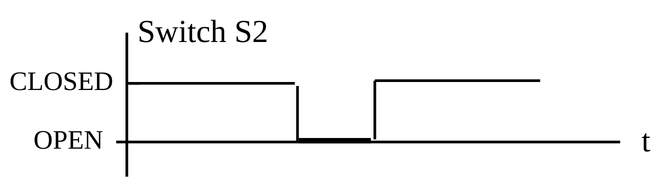


2. Given the following series switching circuit with switches S_1 and S_2

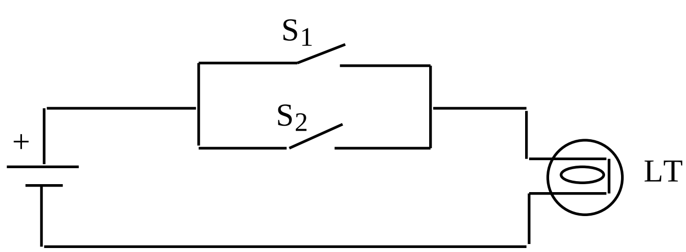


a. Write a complete sentence for when LT is ON like the one you wrote for Problem (1a)
b. Draw the timing diagram for LT given the following timing diagrams for S_1 and S_2





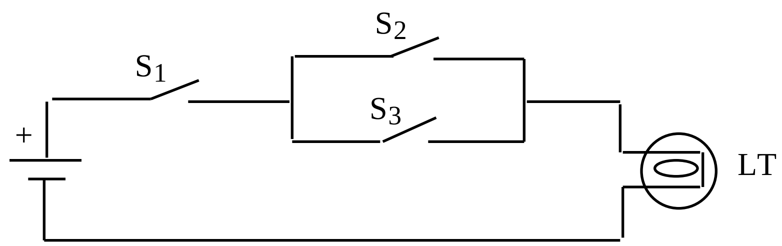
3. Repeat Problem (2) for the following parallel switching circuit



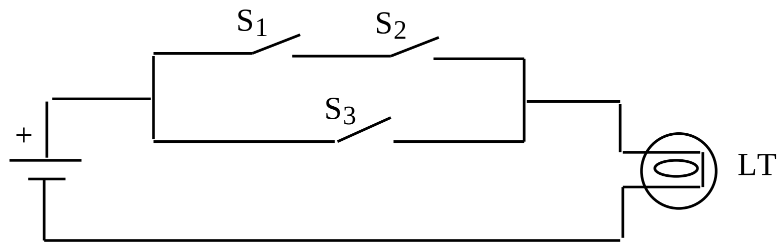
Note that when we say S_1 OR S_2 is CLOSED we include the case when both are CLOSED.

4. Write out sentences for when LT is ON in each of the following switching circuits. Make sure your sentences aren't the same.

a.



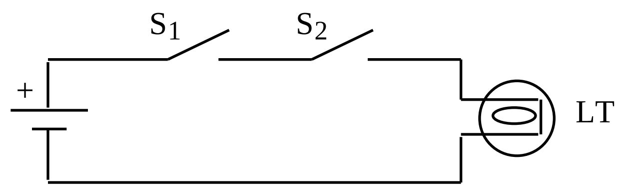
b.



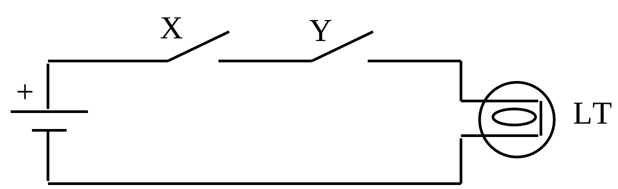
5. Make up your own diagram of a switching circuit containing at least three switches and a Light LT. Then
   a. Write a sentence for when LT is ON
   b. Draw a sample timing diagram

6. Using sentences to describe the operation of switching circuits like we did in Problems (1-5) can be very useful - especially in the early design phases of a digital system. But sentences like ours can get complicated. So there's a real need for alternative ways to describe what's going on in larger switching circuits.

   The objective of this problem is to introduce what we refer to as **Truth Tables**. Truth Tables are tables that tell us when a Light LT in a switching circuit is ON and when it's OFF for every possible *combination* of the switches being OPEN and CLOSED. Let us illustrate the idea of a Truth Table with our simple series switching circuit as follows



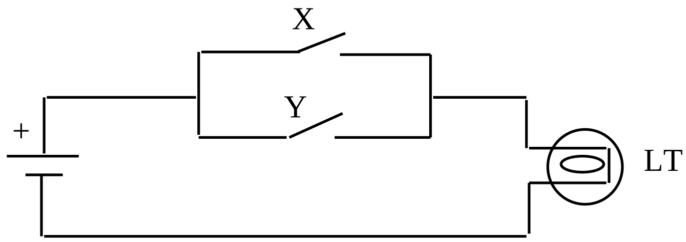
   In order to facilitate what we're going to be doing in later investigations let us redraw the circuit diagram as follows



   with ***X and Y equal to the signals controlling the switches***. With X and Y taking on the values OPEN (for OPEN Switch) and CLOSE (for CLOSE Switch) our Truth Table for our series switching circuit is the following

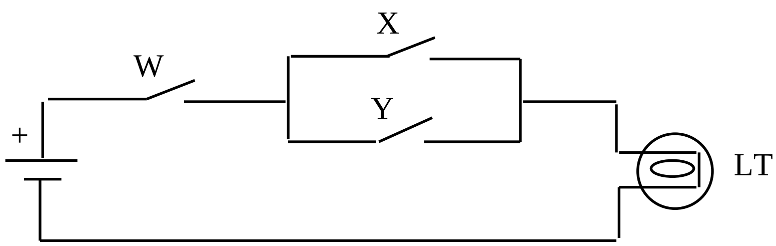
X	**Y**	**LT**
OPEN	OPEN	OFF
OPEN	CLOSE	OFF
CLOSE	OPEN	OFF
CLOSE	CLOSE	ON

Since Truth Tables are able to tell us what's going on in switching circuits by simply telling us when the Light LT is ON and when it's OFF for every possible *combination* of values of X and Y we refer to such circuits as **combinational circuits**. **Memorize** this definition. Then write out the Truth Table for the following parallel switching circuit

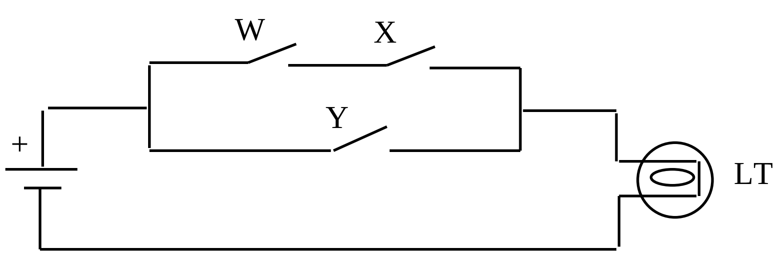


7. Write out the Truth Tables for each of the following switching circuits

a.



b.



8. The signals X and Y that control the switches in digital circuits typically do so by applying HIGH and LOW voltages. Assuming that HIGH voltages H and LOW voltages L cause our switches to OPEN and CLOSE as follows

CONTROLLING VOLTAGE	SWITCH
L	OPEN
H	CLOSED

and that HIGH and LOW voltages cause our lights to turn ON and OFF as follows

LIGHT VOLTAGE	LIGHT
L	OFF
H	ON

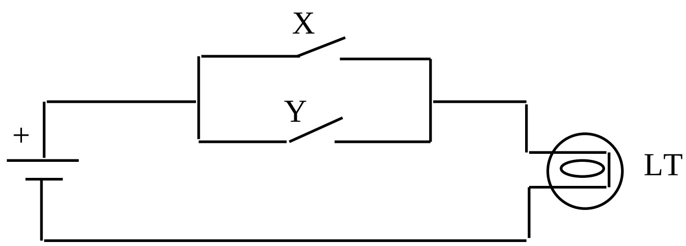
we see that the Truth Table for a switching circuit like the series one in Problem (6) as follows

X	**Y**	**LT**
OPEN	OPEN	OFF
OPEN	CLOSE	OFF
CLOSE	OPEN	OFF
CLOSE	CLOSE	ON

can be rewritten in terms of H's and L's as follows

X	**Y**	**LT**
L	L	L
L	H	L
H	L	L
H	H	H

Make use of these results to write the Truth Table for the following parallel switching circuit in terms of H's and L's



9. Write out the Truth Tables for the switching circuits in Problem (7) in terms of H's and L's.

10. What's an advantage of Truth Tables over the use of sentences for describing the operation of switching circuits.

11. Complete the following for counting in binary from 0 to 15

0000
0001
.
.
1111