PhyzLab: Logic Gates

an investigation of boolean logic through the use of switched electric circuits

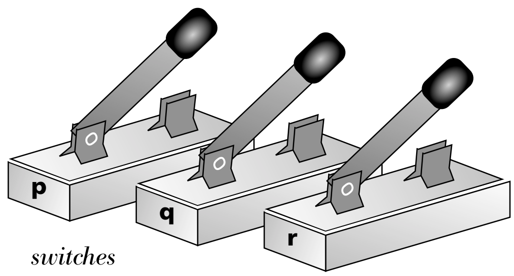
PERIOD	1.		
	2.		
GROUP	3.		
	4.		

• Purpose •
In this activity, you will design electrical circuits that will turn on a light only when certain conditions are met. Each case will require a specific wiring configuration.

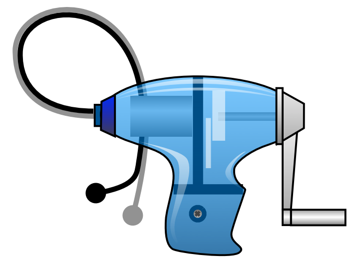
• Apparatus •
___ low-voltage power source (Note: 1.5-V—6-V batteries and Genecons ***are*** recommended; power supplies and 9V batteries are ***not*** recommended)
___ 3 single pole, single throw knife switches (labeled **p**, **q**, and **r**)
___ 1 miniature light bulb in socket (voltage rating appropriate for the power source)
___ 7 connecting wires (5 if using a Genecon)

mini bulbs in sockets

connecting wires



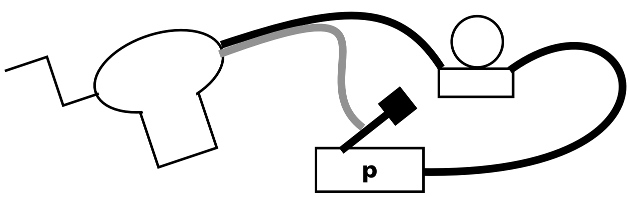
switches

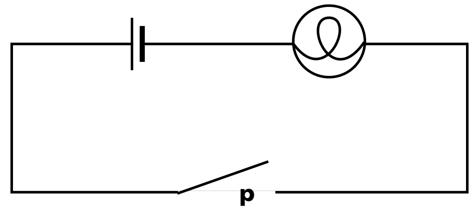


Genecon hand-held generator

• Procedure •
1. The IF-THEN Switch
Construct a circuit such that the light can be controlled by a single switch (**p**). IF the switch blade is down (closed), THEN the light is on; if the switch blade is up (open), the light is off.

Draw a **picture** *and* a **schematic diagram** of your circuit below (already done).





Before designing the circuits on the pages that follow, read these important notes.

• DESIGN EACH CIRCUIT SCHEMATICALLY FIRST. Then build it, test it, draw a picture of it, etc. You will waste time and get frustrated if you try to "guess and check" your way through this lab.

• Each circuit starts with one connection to each terminal of the battery. (Genecon lead wires do this automatically.) One connection leads to the bulb. Another wire is attached to the opposite terminal of the bulb. In other words, each circuit starts out exactly like the one shown above if you remove switch "p."

If you are using a battery or batteries (instead of a Genecon), be sure to do the following.

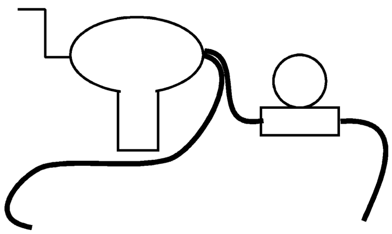
• While you are connecting the switch system you designed, remove one wire from the battery. Attach it only while you test the validity of your circuit. Do not allow a single alligator clip to come in contact with both terminals of the battery at the same time.

• Avoid battery-destroying short circuits. Do not give the current the option of passing across the terminals of the battery with no resistance (unless the circuit calls for that). Make the current pass through the bulb. THINK LIKE CURRENT!

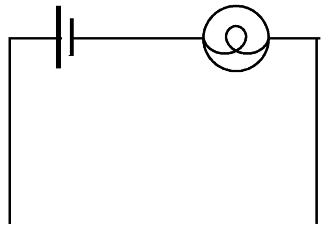
2. The AND Gate: p · q
Construct a circuit such that the light is controlled by *two* switches (**p** and **q**). If *both* switches are closed, the light is on; if *either* switch is open, the light is off. In terms of logic, this represents an AND gate because the bulb will light only IF switch **p** AND switch **q** are closed. In symbols, this is written **p · q.**

a. Draw a **picture** and a **schematic** diagram of your circuit (**label** all switches in the circuit).
b. Complete a **truth table** for the circuit.

PICTURE



SCHEMATIC



TRUTH TABLE

SWITCH p	SWITCH q	BULB p · q
0	0	0
0	1	0
1	0	0
1	1	1

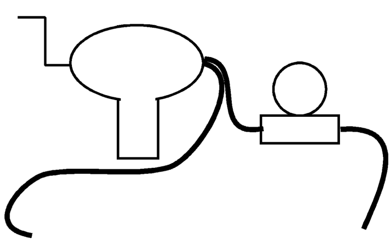
IMPORTANT NOTE: A switch value of "0" means the switch is open, "1" means the switch is closed. A $p \cdot q$ value of "0" means the bulb is OFF; "1" means the bulb is ON.

3. The OR Gate: p + q
Construct a circuit such that the light is controlled by *two* switches (**p** and **q**). If *either* switch is closed, the light is on; if *both* switches are open, the light is off; if both switches are *closed*, the light is on. In terms of logic, this represents an OR gate because the bulb will light only IF **p** OR **q** is closed. In symbols, this is written **p + q.**

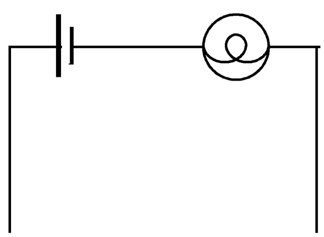
Remember to DESIGN THE CIRCUIT SCHEMATICALLY FIRST. Then build it, test it, draw a picture of it, etc. You will waste time and get frustrated if you try to "guess and check" your way through this lab.

a. Draw a **picture** and a **schematic** diagram of your circuit (**label** all switches in the circuit).
b. Complete a **truth table** for the circuit.

PICTURE



SCHEMATIC



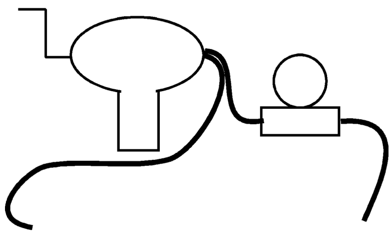
TRUTH TABLE

p	q	p + q
0	0	
0	1	
1	0	
1	1	

4. Double AND: p · q · r
Construct a circuit such that the light is controlled by *three* switches (**p**, **q** and **r**). If *all* switches are closed, the light is on; if **any** switch is open, the light is off. In terms of logic, this represents a double AND because the bulb will light only IF **p** AND **q** AND **r** are closed. In symbols, this is written **p · q · r.**

a. Draw a **picture** and a **schematic** diagram of your circuit (**label** all switches in the circuit).
b. Complete a **truth table** for the circuit.

PICTURE SCHEMATIC TRUTH TABLE



p	q	r	p · q · r
0	0	0	
0	0	1	
0	1	0	
0	1	1	
1	0	0	
1	0	1	
1	1	0	
1	1	1	

5. Double OR: p + q + r
Construct a circuit such that the light is controlled by *three* switches (**p**, **q** and **r**). If *any* switch is closed, the light is on; if *all* switches are open, the light is off. In terms of logic, this represents a double OR because the bulb will light only IF **p** OR **q** OR **r** is closed. In symbols, this is written **p + q + r.**

a. Draw a **picture** and a **schematic** diagram of your circuit (**label** all switches in the circuit).
b. Complete a **truth table** for the circuit.

PICTURE SCHEMATIC TRUTH TABLE

REALITY CHECK: Do you have values of "2" or "3" in your truth table? If so, you are mistaken. Check the note below the first truth table (in circuit 2).

6. Compound Gate 1: p · (q + r)
Construct a circuit such that the light is controlled by *three* switches such that the bulb will light IF **p** AND (**q** OR **r**) are closed. If **p** is open, the light is off; if **p** is closed but **q** and **r** are open, the light is off; if **p** is closed and either **q** or **r** is closed, the light is on. Symbolically, this is written **p · (q + r)**.

Remember to DESIGN THE CIRCUIT SCHEMATICALLY FIRST. Then build it, test it, draw a picture of it, etc. You will waste time and get frustrated if you try to "guess and check" your way through this lab.

a. Draw a **picture** and a **schematic** diagram of your circuit (LABEL all switches in the circuit).
b. Complete a **truth table** for the circuit.

PICTURE

SCHEMATIC

TRUTH TABLE

p	q	r	p · (q + r)

7. Compound Gate 2: p + (q · r)
Construct a circuit such that the light is controlled by *three* switches such that the bulb will light IF **p** OR (**q** AND **r**) are closed. If **p** is open and **q** or **r** are open, the light is off; if **p** is closed but **q** and **r** are open, the light is on; if **p** is open but both **q** and **r** are closed, the light is on. Symbolically, this is written **p + (q · r)**.

1. Draw a **picture** and a **schematic** diagram of your circuit (LABEL all switches in the circuit).
2. Complete a **truth table** for the circuit.

PICTURE

SCHEMATIC

TRUTH TABLE

8. The IF-NOT Switch: ~ p
Construct a circuit such that the light is controlled by *one* switch such that IF **p** is NOT closed, the bulb will light. If **p** is open, the light is on; if **p** is closed, the light is off. In symbols, this is written **~ p**.

Battery note (disregard if using a Genecon): TEST THE SWITCH ONLY BRIEFLY; USING THE CORRECTLY WIRED SWITCH TO KEEP THE LIGHT OFF FOR LONG INTERVALS WILL DESTROY THE BATTERY!

That note was in fact a hint that a short circuit is involved in this circuit. But start the circuit as you were previously instructed to start all circuits (see the "Each" note at the bottom of the first page.)

Draw a **picture** and a **schematic** diagram of your circuit (**label** all switches in the circuit).

PICTURE SCHEMATIC

9. The NOT Gate: p ~ q
Construct a circuit such that the light is controlled by *two* switches such that the bulb will light IF **p** NOT **q** is closed. If **p** is open, the light is off; if **p** is closed but **q** is open, the light is on; if **q** is closed, the light is off. In symbols, this is written **p ~ q**.

Battery note (disregard if using a Genecon): TEST THE SWITCH ONLY BRIEFLY; USING THE CORRECTLY WIRED SWITCH "q" TO KEEP THE LIGHT OFF FOR LONG INTERVALS WILL DESTROY THE BATTERY!

a. Draw a **picture** and a **schematic** diagram of your circuit (**label** all switches in the circuit).
b. Complete a **truth table** for the circuit.

PICTURE SCHEMATIC TRUTH TABLE

p	q	p ~ q
0	0	
0	1	
1	0	
1	1	

10. The AND-NOT Gate: p · q ~ r

Construct a circuit such that the light is controlled by *three* switches such that the bulb will light IF **p** AND **q** NOT **r** are closed. If **p** or **q** is open, the light is off; if **p** and **q** are closed but **r** is open, the light is on; if **r** is closed, the light is off. In symbols, this is written **p · q ~ r.**

Battery note (disregard if using a Genecon): TEST THE SWITCH ONLY BRIEFLY; USING THE CORRECTLY WIRED SWITCH "r" TO KEEP THE LIGHT OFF FOR LONG INTERVALS WILL DESTROY THE BATTERY!

a. Draw a **picture** and a **schematic** diagram of your circuit (**label** all switches in the circuit).
b. Complete a **truth table** for the circuit.

PICTURE SCHEMATIC TRUTH TABLE

11. The OR-NOT Gate: p + q ~ r

Construct a circuit such that the light is controlled by *three* switches such that the bulb will light IF **p** OR **q** NOT **r** are closed. If **p** and **q** are open, the light is off; if **p** or **q** are closed but **r** is open, the light is on; if **r** is closed, the light is off. In symbols, this is written **p + q ~ r**.

Battery note (disregard if using a Genecon): TEST THE SWITCH ONLY BRIEFLY; USING THE CORRECTLY WIRED SWITCH "r" TO KEEP THE LIGHT OFF FOR LONG INTERVALS WILL DESTROY THE BATTERY!

a. Draw a **picture** and a **schematic** diagram of your circuit (**label** all switches in the circuit).
b. Complete a **truth table** for the circuit.

PICTURE SCHEMATIC TRUTH TABLE
