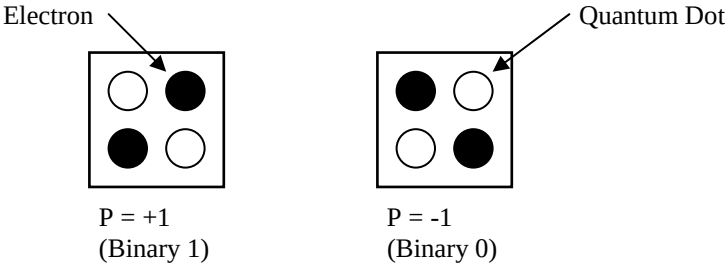
Quantum-Dot Cellular Automata (QCA)

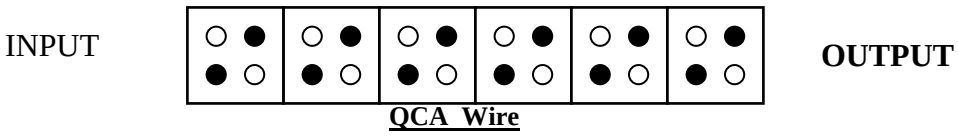
Quantum dots are nanostructures [*nano-:* one billionth part of] created from standard semiconductive material. A quantum dot can be visualized as a well. Electrons, once trapped in the dot, do not alone posses the energy required to escape. Binary information is stored in the charge configuration within a cell rather than in the on/off state of a current switch.

Each cell consists of four dots and contains two mobile electrons, which occupy antipodal ("exact opposite") sites.



Because the electrons are quantum mechanical parts they are able to tunnel between the dots in a cell. The electrons in cells adjacent to each other will interact. As a result, the polarization of one cell will be directly affected by the polarization of its neighboring cells.

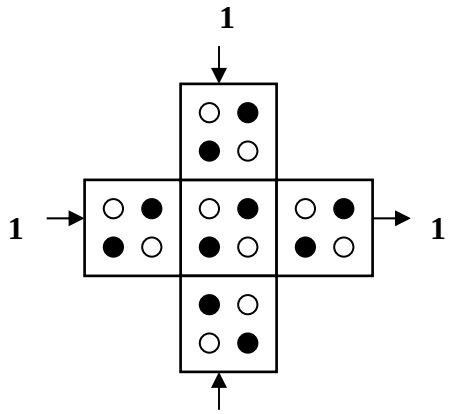
This interaction forces neighboring cells to synchronize their polarization. Therefore, an array of QCA cells acts as a wire and is able to transmit information from one end to the another. All the cells in the wire will switch their polarization to follow that of the input or driver cell.



In order to perform general computation, a set of Boolean logic gates is required to perform the AND, OR, NOT, and FANOUT operations.

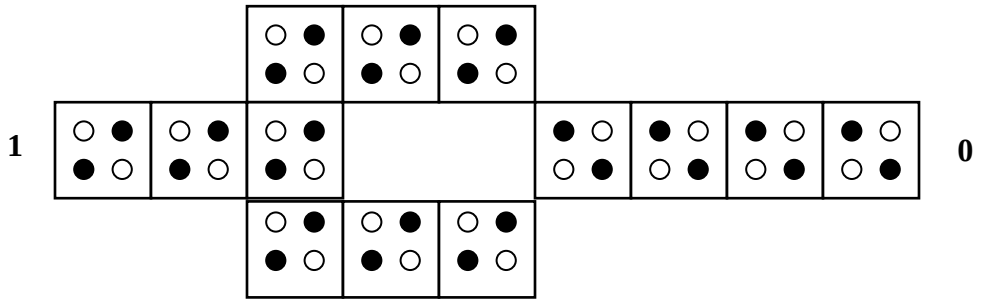
The QCA majority gate produces an output, which reflects the majority of the inputs. Majority gates can be used to implement AND and OR gates:

- By setting one of the inputs of the majority gate to 0 we create an AND gate.
- If we set one of the inputs to a 1 we produce an OR gate.



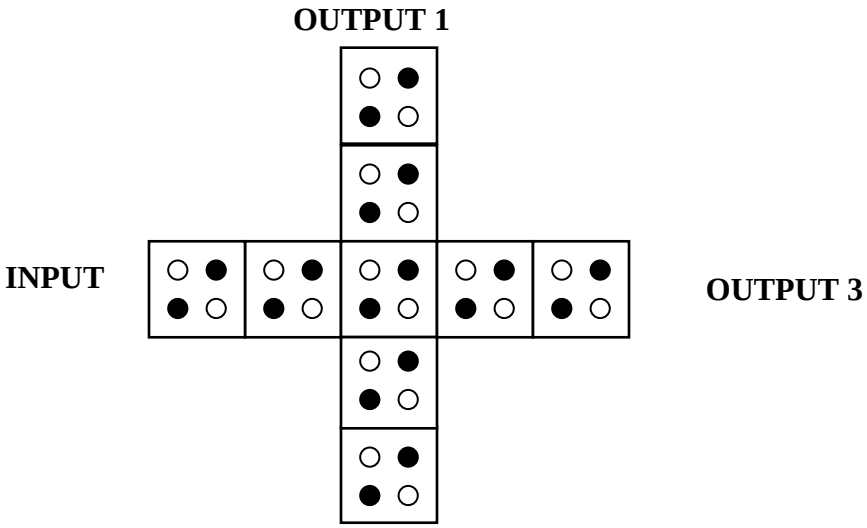
QCA Majority Gate

To implement the inverter or NOT gate, cells are positioned at 45 degrees with respect to each other, and will interact inversely; their polarization is always inverted ("changed to the direct opposite").



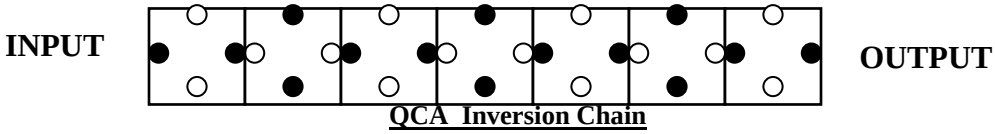
QCA NOT- or Inverter Gate

In a FANOUT, one signal comes in and several copies go out. Each output reflects the input.



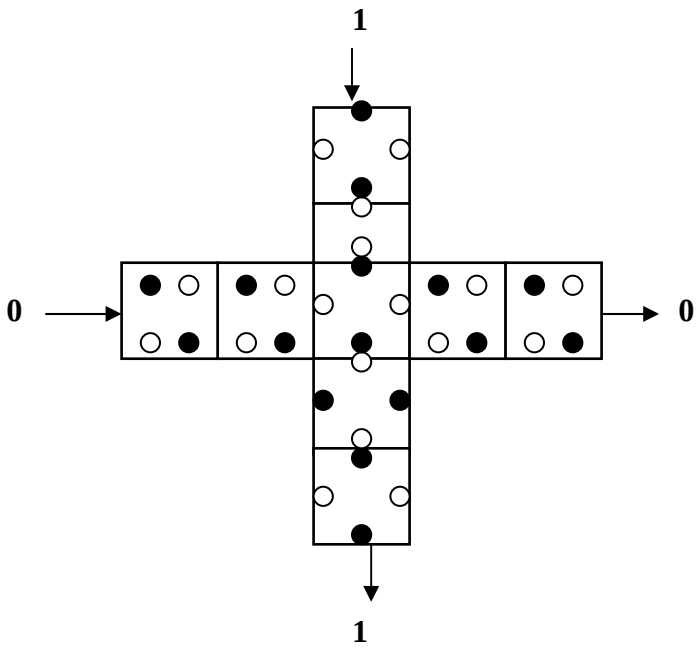
QCA Fanout

When the dots in a cell are rotated 45 degrees, the cells will act inversely. A wire created with these 45-degree cells will form an "inversion chain," where each cell in the chain takes on the opposite polarization of its nearest neighbors.



QCA Inversion Chain

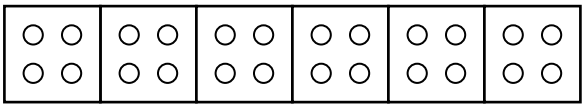
In a QCA crossover, a wire of regular cells crosses a wire of 45-degree cells. Here, the two wires do not interact, meaning that information along one wire will not interact with information along the crossed wire – signals can be crossed directly over each other.



QCA Crossover

Worksheet 1: Complete each diagram with the missing electrons.

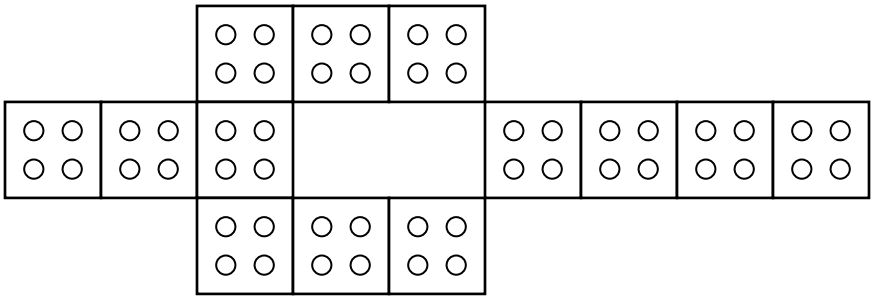
1. **INPUT**



OUTPUT

QCA Wire

2. **1**

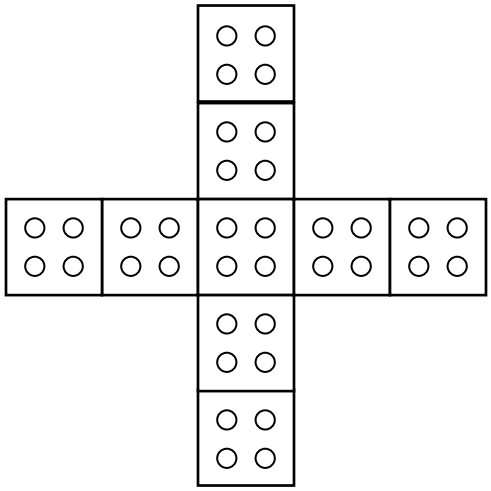


0

QCA NOT- or Inverter Gate

OUTPUT 1

3. INPUT

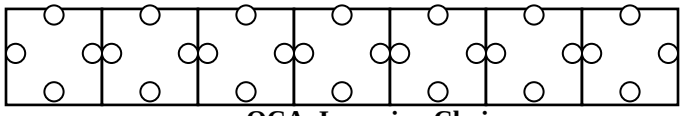


OUTPUT 3

OUTPUT 2

QCA Fanout

4. **INPUT**

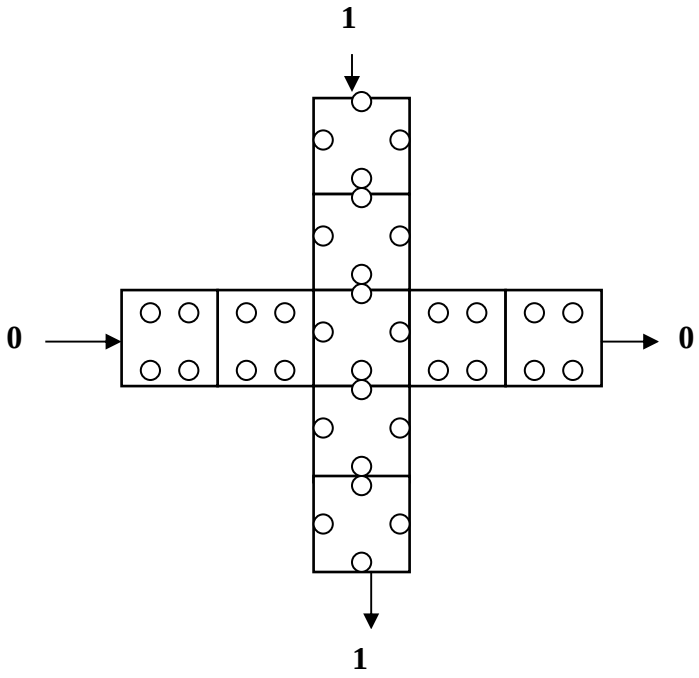


OUTPUT

QCA Inversion Chain

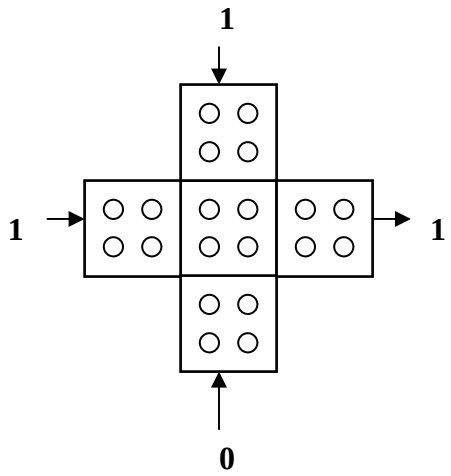
Worksheet 1 - continued

5.



QCA Crossover

6.



QCA Majority Gate

Peer Team Project

- Each team will be responsible for re-creating a QCA-circuit layout.
- Both members of the team will equally share the tasks associated with the project.
- Each team will receive large sheets of paper, sheets with cutout cells, scissors, glue, and a diagram to be re-created. Coloring utensils will be available, if needed.
- The project should be finished by the end of this class period.

Step 1: Decide on how many QCA cells you need of each type.

Step 2: Cut the cells out that you need.

Step 3: Glue the cells on the poster paper, creating your circuit according to the diagram.

Step 4: Fill-in the color of the Quantum Dots for the electrons.

Step 5: Label your diagram.

Step 6: Make sure to write the names of both team members, as well as the class period on the project.

COOPERATIVE - LEARNING GROUND RULES

1. **Cooperate with everyone in your group.**
2. **Give praise liberally.**
3. **Use no put-downs.**
4. **Listen carefully to others.**
5. **Get all ideas out in the open. (There's no such thing as a bad idea!)**
6. **Achieve a group solution for each problem.**
7. **Make sure that everyone understands the solution before continuing.**
8. **Share the leadership of the group.**
9. **Make sure that everyone participates and no one dominates.**

Discussion Log

Name:_____ Period:_____ Date:_____

1. **What I expected to learn today was:**
   _____
   _____
   _____

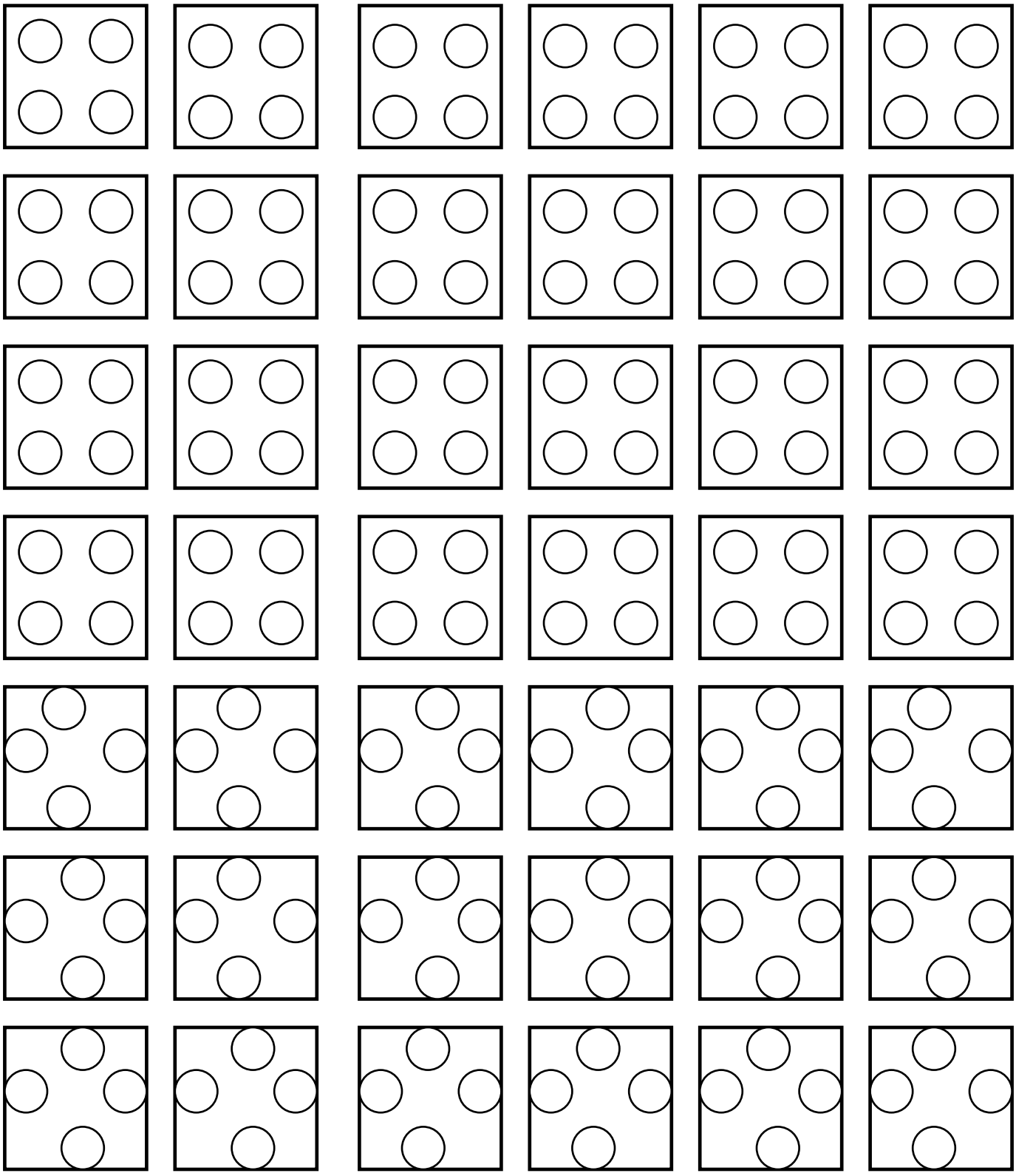
2. **What I would like to know more about nanocomputers is:**
   _____
   _____
   _____

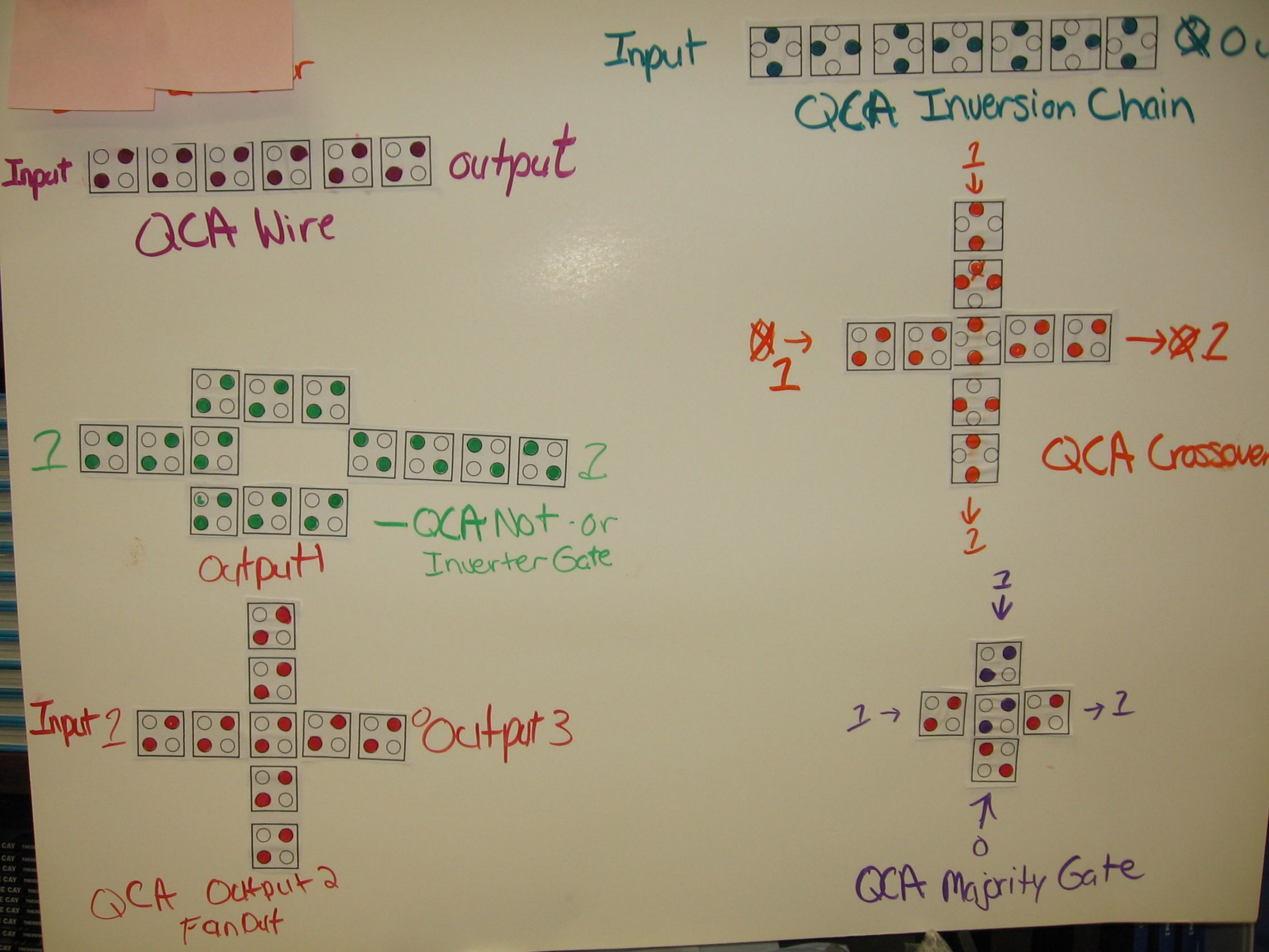
3. **What I have learned from this lesson is:**
   _____
   _____
   _____

4. **What I liked / did not like about the work with my peer was:**
   _____
   _____
   _____

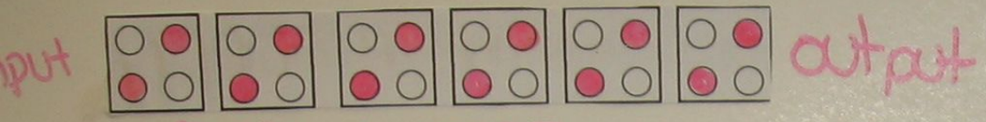
5. **Additional comments or suggestions I would like to make are:**
   _____
   _____
   _____

Cutouts



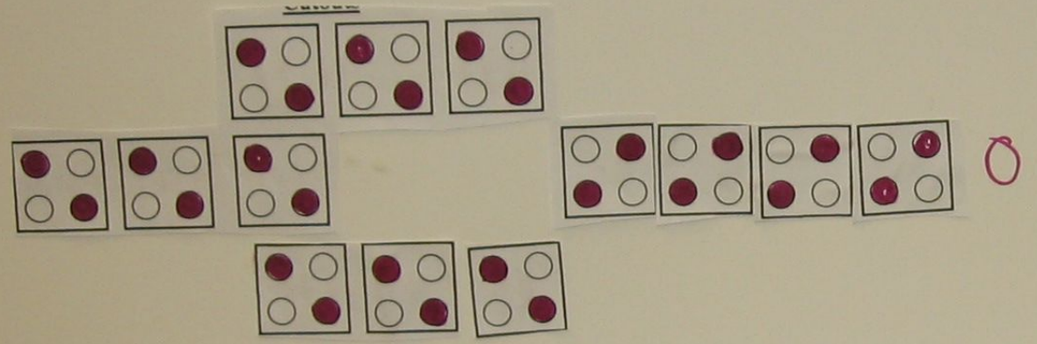

Input
output
QCA Wire
Input
QCA Inversion Chain
1
1
1
QCA Crossover
1
1
QCA Not - or
Inverter Gate
Output
Input 1
Output 3
Output 2
QCA Output 2
FanOut
1
1
0
QCA Majority Gate

1.



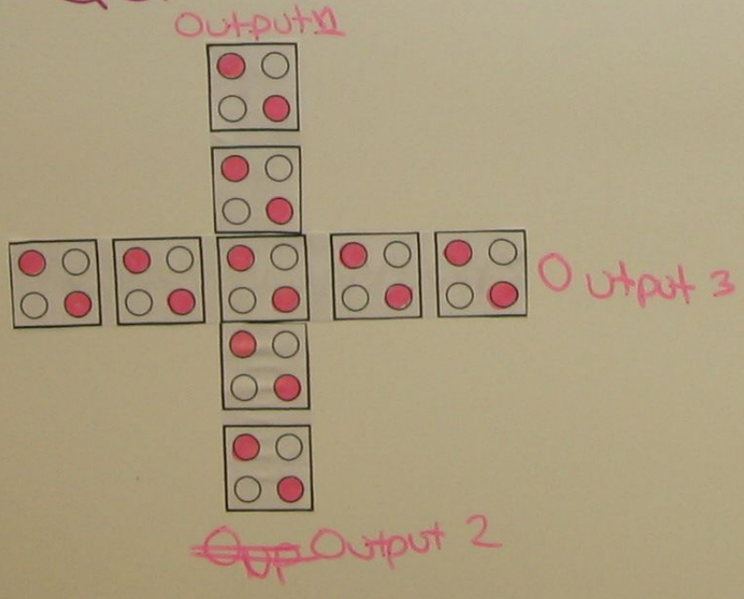
QCA WIRE

2.



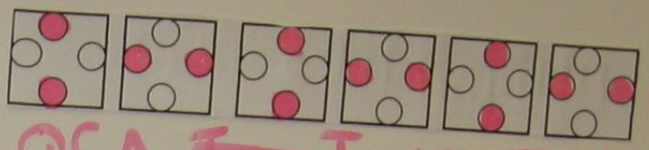
QCA NOT- or Inverter Gate

3.

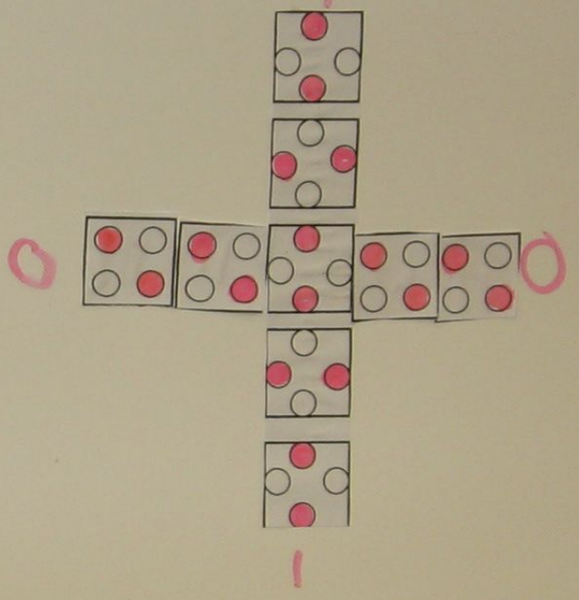


QCA Fanout

4.

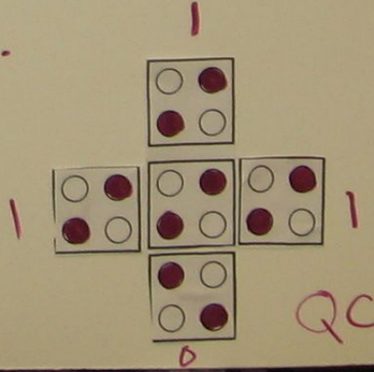


QCA ~~Inverter~~ Inversion Chain



QCA Crossover

6.

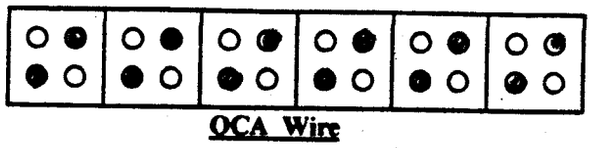


QCA Majority Gate

83/100 3/23/17 R.2

Worksheet 1: **Complete each diagram with the missing electrons.**

1. **INPUT**

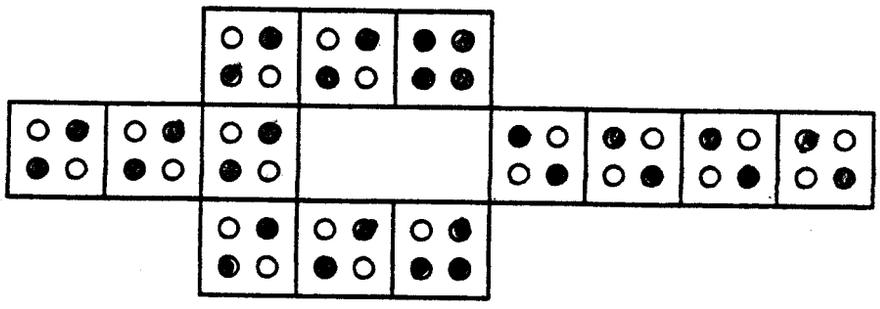


OUTPUT

QCA Wire

-1/4

2. **1**

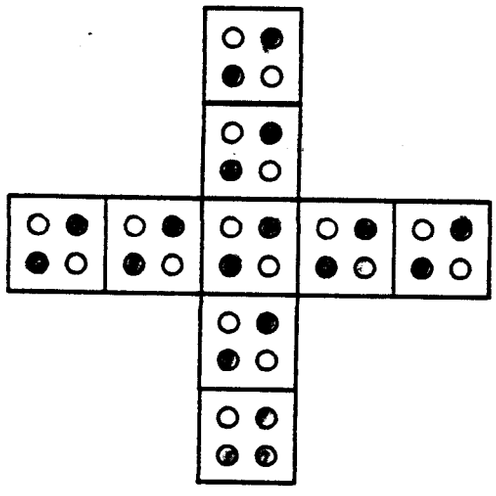


0

QCA NOT- or Inverter Gate

OUTPUT 1

3. **INPUT**



OUTPUT 3

OUTPUT 2

QCA Fanout

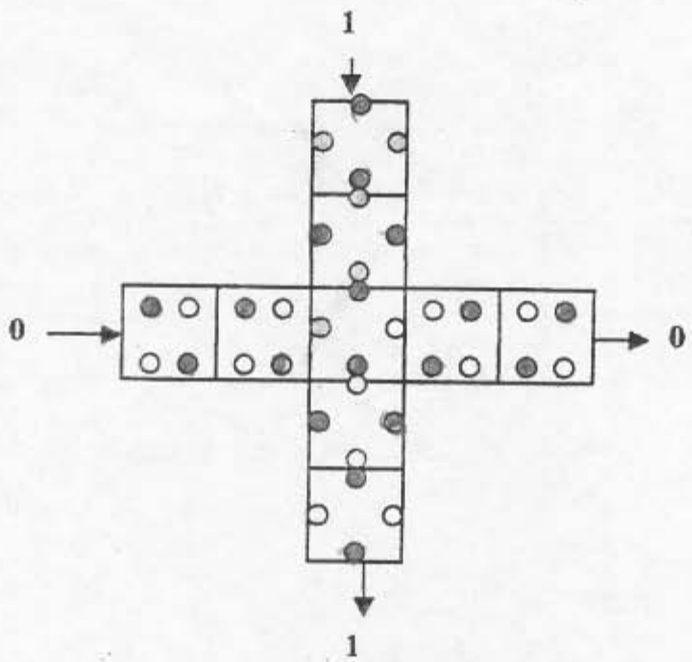
4. **INPUT**

OUTPUT

QCA Inversion Chain

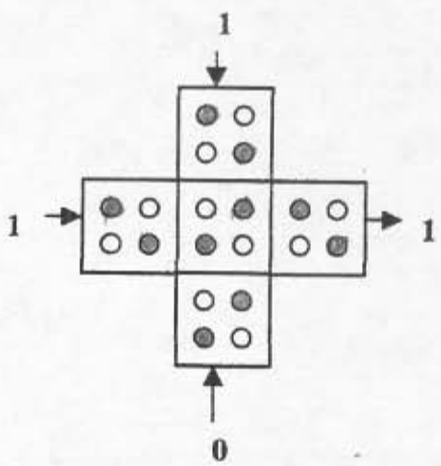
Worksheet 1 - continued

5. $-\frac{1}{2}$



QCA Crossover

6. $-\frac{1}{4}$



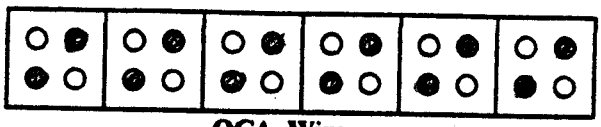
QCA Majority Gate

92/100

2

Worksheet 1: **Complete each diagram with the missing electrons.**

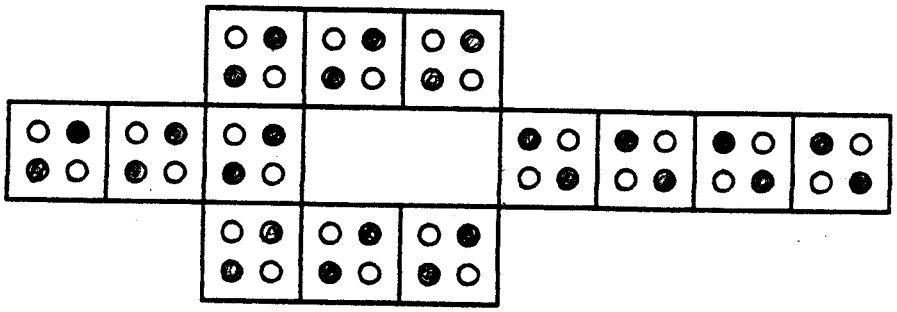
1. **INPUT**



OUTPUT

QCA Wire

2. **1**

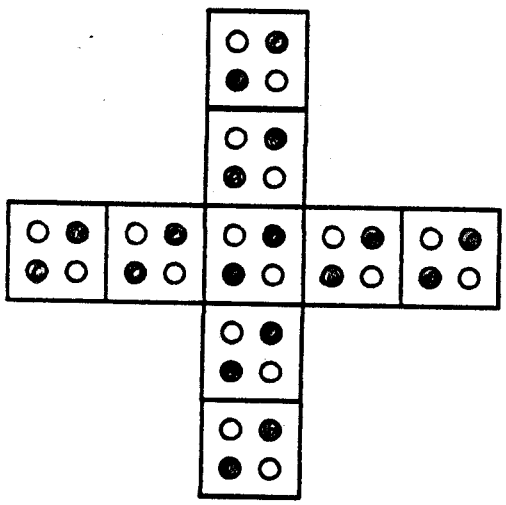


0

QCA NOT- or Inverter Gate

OUTPUT 1

3. **INPUT**

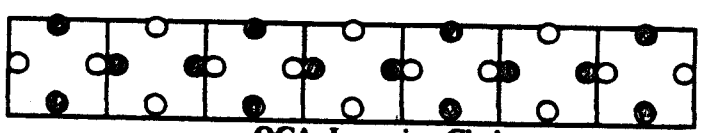


OUTPUT 3

OUTPUT 2

QCA Fanout

4. **INPUT**

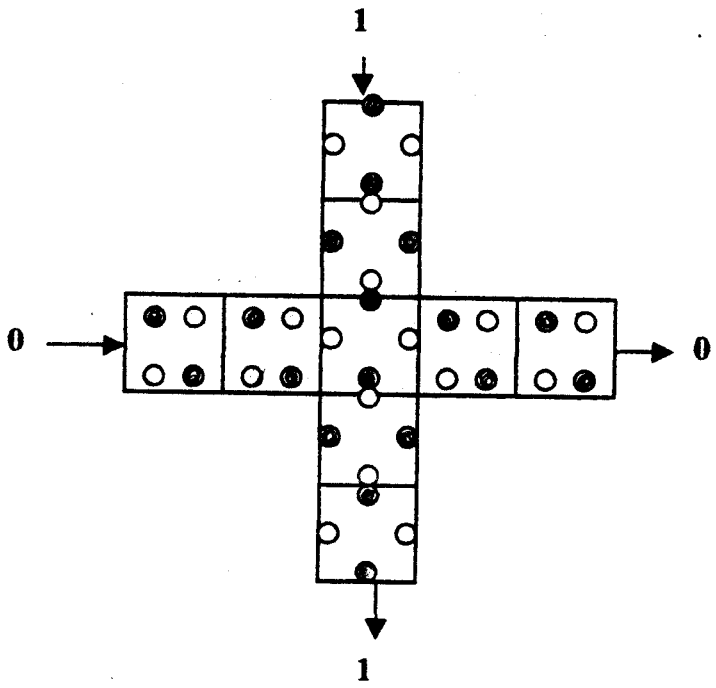


OUTPUT

QCA Inversion Chain

Worksheet 1 - continued

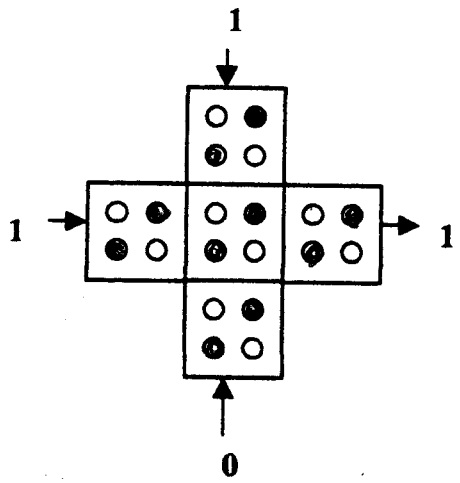
5.



OCA Crossover

$-\frac{1}{2}$

6.



OCA Majority Gate

Discussion Log

Period: 2 **Date:** 3/26/7

1. **What I expected to learn today was:**
   about math equations that we were going to face in the future.

2. **What I would like to know more about nanocomputers is:**
   how do they function

3. **What I have learned from this lesson is:**
   what nanocomputers are.

4. **What I liked / did not like about the work with my peer was:**
   I liked the activities, I did not like

5. **Additional comments or suggestions I would like to make are:**
   that it was a great time of learning.

Discussion Log

N

Period: 1 Date: 3/21/06

1. **What I expected to learn today was:**
I was expected to learn about websites.

2. **What I would like to know more about nanocomputers is:**
How the little dot things in the chips get bigger.

3. **What I have learned from this lesson is:**
The things in the chips have to be as far away from eachother as posible.

4. **What I liked / did not like about the work with my peer was:**
I couldnt really understand her.

5. **Additional comments or suggestions I would like to make are:**
None.

Discussion Log

N Period: 2nd Date: 3-20-07

1. **What I expected to learn today was:**
   learn about computers

2. **What I would like to know more about nanocomputers is:**
   How they process

3. **What I have learned from this lesson is:**
   How nanocomputers work

4. **What I liked / did not like about the work with my peer was:**
   I liked the poster and the activities

5. **Additional comments or suggestions I would like to make are:**
   I had alot of fun