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Rush Hour Mayhem:

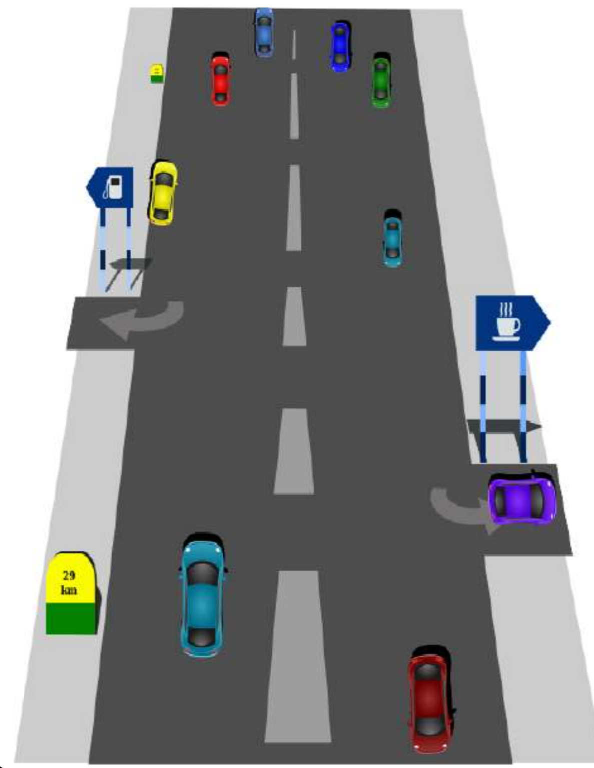
Engineering Efficient Routes With Logic Gates

U.S. National Science Foundation

Engineering & Applied Science
UNIVERSITY OF COLORADO BOULDER

Rush Hour Mayhem

- The mayor has hired you as city planners to help reduce traffic in the downtown area.
- However, it is essential that all of the businesses downtown still receive the correct shipments of goods.
- Make sure that the red and green delivery trucks that are coming into the city get to the right places!



Free SVG (2014)

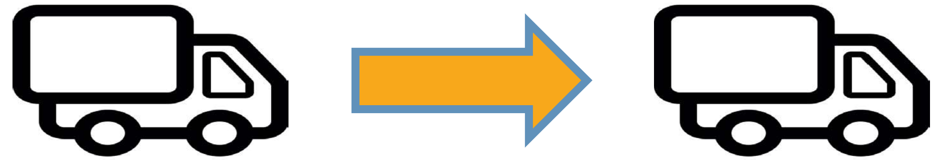
Rules

- Strategically use a series of gates to help send the right trucks to the right places.
- Gate Types:
  - Buffer
  - OR
  - NOT
  - AND
- Each gate works differently.

Vector Portal (2022)

Single Gates

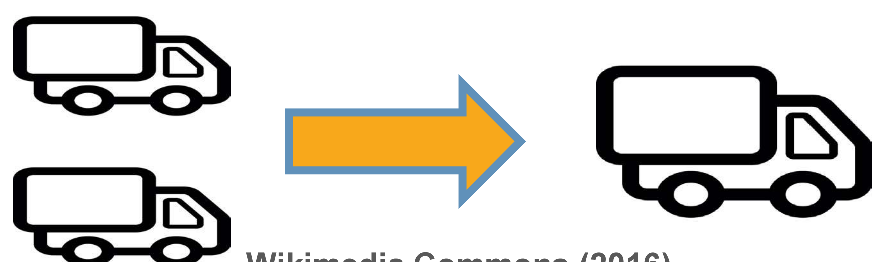
- One truck comes in, one truck goes out.
  - BUFFER Gate
  - NOT Gate



Wikimedia Commons (2016)

Dual Gates

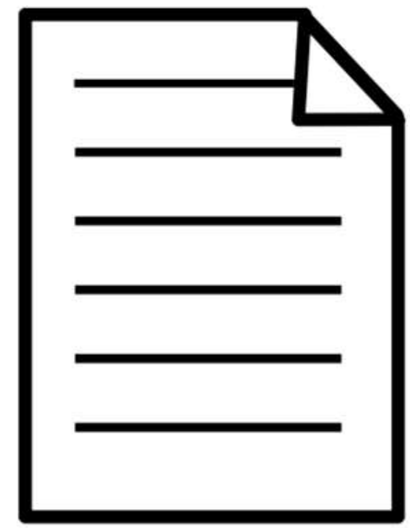
- Two trucks come in, one truck comes out.
  - AND Gate
  - OR Gate



Wikimedia Commons (2016)

Gate Handout #1

- The truth tables show how each type of gate works.
- They will show what trucks will come out of the gates (the output) based on what went in (the input(s)).
- Study the truth tables and decide which type of gate applies to each example.



Free SVG (2014)

Review: Single Gates

- One truck comes in, one truck goes out.
- BUFFER Gate
  - Allows the truck to go through unchanged.
  - Green → Buffer Gate → Green
  - Sometimes called a "repeater."
- NOT Gate
  - Changes the type of truck.
  - Green → NOT Gate → Red
  - Sometimes called an "inverter."

Raw Pixel (2025)

Review: Dual Gates

- Two trucks come in, one truck comes out.
- AND Gate
  - Are <u>both</u> trucks green?
  - Yes = Green truck comes out.
  - No = Red truck comes out.
- OR Gate
  - Is <u>either</u> of the trucks green?
  - Yes = Green truck comes out.
  - No = Red truck comes out.

Public Domain Vectors
(2020)

Extra Check!

- Check your understanding of how these four gates work:

- Red Truck → Buffer Gate → Red Truck
- Red Truck → NOT Gate → Green Truck
- Red + Green Truck → AND Gate → Red Truck
- Red + Green Truck → OR Gate → Green Truck

City Map #1 - Version A

- Now that you know how the gates work, it’s up to you help sort out the mess of trucks downtown.
- The previous city planner set up a series of gates. Determine which trucks should end up at the drop-off points.

Wannapik (2015)

City Map #1 - Version B

- Uh oh! There’s a new set of trucks heading into town!
- Change the gates to make sure that the correct trucks end up at the drop-off points!

Wannapik (2015)

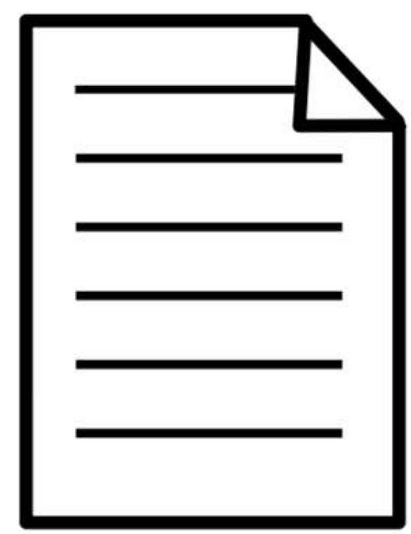
Congratulations!

- Great job, City Planners!
  - You’ve successfully gotten the correct trucks to the drop-off points.
- The mayor has decided to promote you to an even more difficult section of the city!
  - We’ll have to learn about some new gates in order to fix this mess.

Wikimedia Commons (2021)

Logic Gate Handout #2

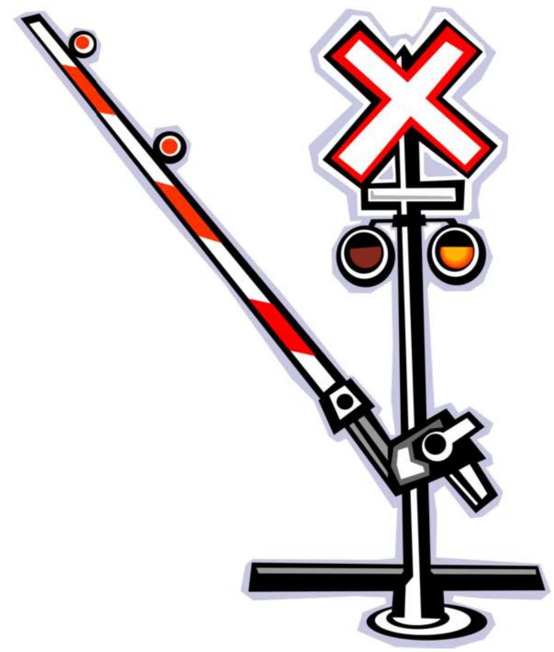
- On your handout, you are given truth tables that show how three new gates work.
  - NAND, NOR, & XOR
- This time you will have to use the names and your knowledge of other gates to determine their outputs.



Free SVG (2014)

Review: Other Dual Gates

- **NAND & NOR Gates**
  - Essentially the inverse of AND and OR
  - NAND = NOT + AND
  - NOR = NOT + OR
- **XOR Gate**
  - Exclusively OR
  - Only returns a green output if the two inputs don't match



Wannapik (2015)

Extra Check!

- **Check your understanding of how these four gates work:**

- **Red + Green Truck → NAND Gate → Green Truck**
- **Red + Red Truck → NOR Gate → Green Truck**
- **Green + Green Truck → XOR Gate → Red Truck**
- **Red + Red Truck → NAND Gate → Green Truck**

City Map #2

- Equipped with these new gates, let's tackle our toughest problem yet!

- The previous city planner set up a series of gates. Determine which trucks should end up at the drop-off points.

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Engineering Design Challenge - Part 1

- This time you will create your own map!
  - The inputs & the final outputs have been selected for you.
- Design Constraints:
  - Use the NOT, Buffer, OR, & AND gates at least once.
  - Use the NOR, NAND, and XOR gates at least twice.
  - 5 cars must go through at least 2 gates.
  - 1 car must go through at least 3 gates.
  - All input trucks must be used.

Why Did We Do This?

- Throughout these activities, I'm sure you've wondered:

  "Why am I doing this?"

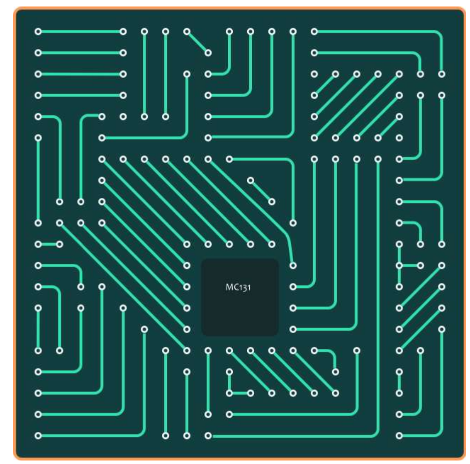
  "What am I supposed to learn from this?"

- Believe it or not, you've been learning about something called <u>logic gates</u>!

Free SVG (2020)

What Are Logic Gates?

- Fundamental building blocks of electrical and digital circuits.
- The foundation of advanced electronics and coding (programming).
- Examples:
  - Computers, phones, tablets, smart-watches, etc.
  - Traffic lights
  - Software



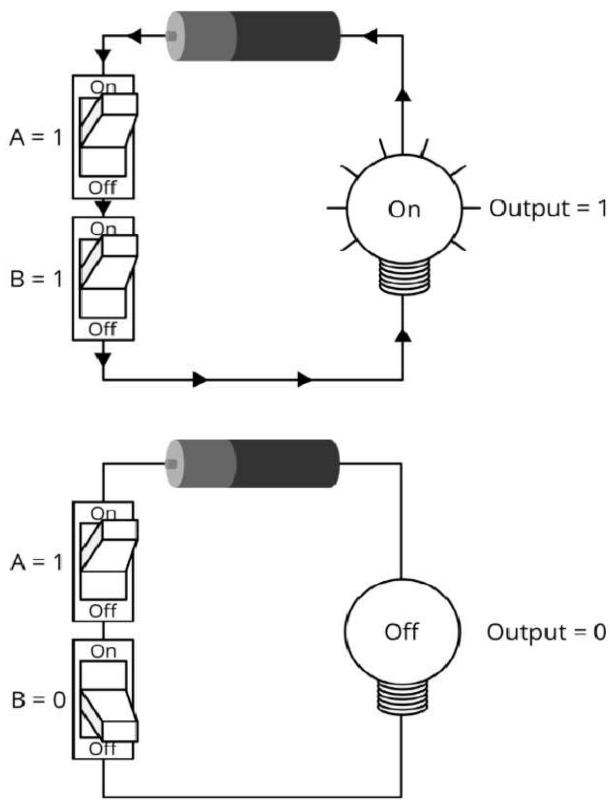
Wikimedia Commons (2011)

How Do They Work?

- Electronics only understand “on” or “off.”
  - Is it receiving a “signal” or not.
- We often represent this as:
  - 0 = No signal
  - 1 = Signal
- What were our 0s and 1s in our city planning?

Public Domain Vectors (2016)

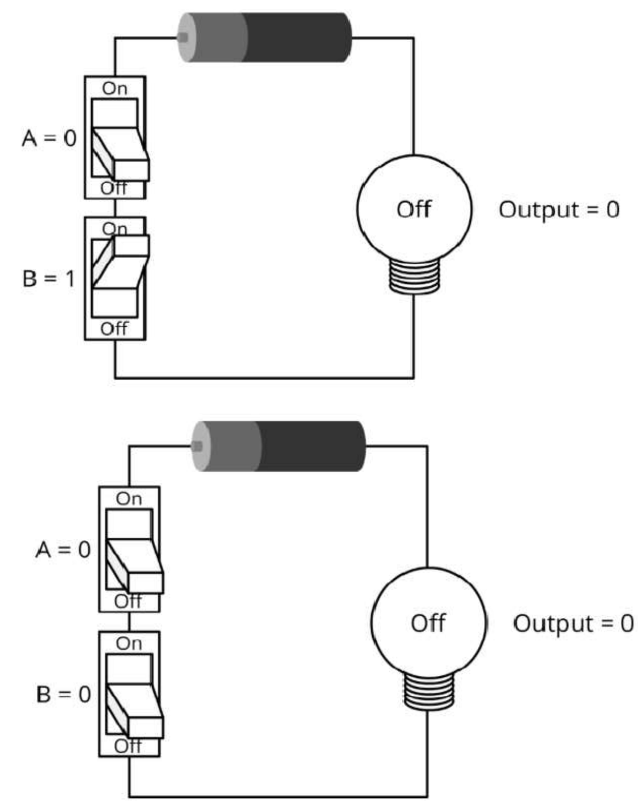
Visualizing Logic Gates



Wong (2022)

Truth Table		
Input A	Input B	Output
1	1	1
1	0	0
0	1	0
0	0	0

Gate = AND



Wong (2022)

Engineering Design Challenge - Part 2

- Efficiency is important, especially in electronics.
  - Leads to lower cost and energy usage.
- Find a way to remove at least 3 gates from your map.
- Design Constraints:
  - You may NOT change any inputs or final outputs.
  - You may change/remove other gates if necessary.
  - There are no longer any constraints regarding the types of gates you use.
  - You CANNOT change your paths/layout.

<u>DON'T START DESIGNING YET**</u>**

Brainstorm and Peer Share!

- Discuss ideas with your partners…
  - DO NOT MAKE THE CHANGES YET!
- When instructed, you will swap your map with another team.
  - Do not talk to them about your map or ideas.
  - In 5 minutes, come up with 2-3 suggestions for how the other group could change their gates.
  - Write these ideas on a separate sheet of paper and return it with the map. Plan to turn in this paper with your final product.

Presentation Requirement

- **Document the changes you make as you go.**
- **You will need to create a slide deck explaining the changes you made.**
- **Each group member must describe at least one gate change and create those related slides.**
  - **Each member is to explain how you managed to keep the same inputs and the same FINAL outputs while changing/reducing the gates.**

REMEMBER:

Each group member must describe at least one gate change and create those related slides.

Content	Score
• Was the information on the presentation complete? Did it answer the question well? • Did the presenter touch on the main idea, or did they talk about something that was not relevant to the topic? • Was the presentation thorough, and were complete thoughts and ideas behind it? • Did the presenter convey the knowledge they learned in an understandable form (i.e., did it make sense)? • Are they able to explain the project further if they are asked questions? Can they extend their knowledge to something more than what is on the slides?	2 4 6 8 10

Mechanics	Score
• Did the presenter make eye contact when talking? Did they have a presence when they were talking in front of everyone? • Were you always able to hear the presenter? Did their audio cues match the visual cues?	2 4

Appearance	Score
• Were appropriate grammar and spelling used in the presentation? • Are the aesthetics professional and easy to read? • Is the presentation cohesive?	2 4 6

Comments	Total Score
	________/20

Engineering Design Challenge - Part 2

- **You can now start!**
- **Remember:**
  - **Find a way to remove at least 3 gates from your map.**
  - **Design Constraints:**
    - **You may NOT change any inputs or final outputs.**
    - **You may change/remove other gates if necessary.**
    - **There are no longer any constraints regarding the types of gates you use.**
    - **You CANNOT change your paths/layout.**

Work Cited

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