FICHA DE PROYECTO – 2025
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TÍTULO: The *VROOM VROOM* Binary Calculator

Centro: Caxton College	**Curso y Ciclo: 4 ESO**
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1. Resumen breve del proyecto y objetivo

Our project aims to design and build a 4-bit binary adding calculator using Hot Wheels, toy cars, to represent binary digits (bits). The goal is to demonstrate how logic gates (AND, OR, XOR) can be used to perform binary addition. We are constructing two input platforms, each with lanes corresponding to the four binary digits. Except for the splitter cars, if a lane contains a Hot Wheels car, it represents a 1, and if a lane is empty, it represents a 0.
When all cars are released, they travel along the track through three mechanical “gates” that simulate the logical operations used in binary addition:

AND Gate

INPUT A	INPUT B	OUTPUT
0	0	0
0	1	0
1	0	0
1	1	1

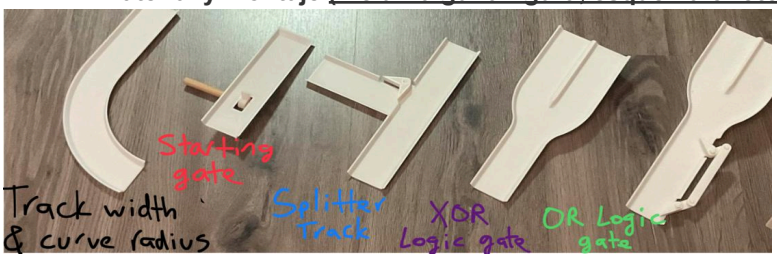
OR Gate

INPUT A	INPUT B	OUTPUT
0	0	0
0	1	1
1	0	1
1	1	1

XOR Gate

INPUT A	INPUT B	OUTPUT
0	0	0
0	1	1
1	0	1
1	1	0

2. Material y montaje (Incluir alguna figura, esquema o fotografía del montaje de resolución medio-baja)



3. Fundamentación: Principios físicos involucrados y su relación con aplicaciones tecnológicas

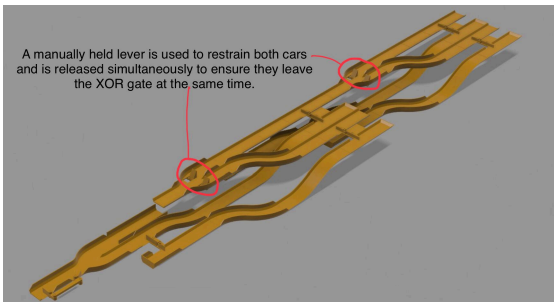
OR Gate: The track is placed on a slope so that each car gains gravitational potential energy, which turns into kinetic energy as it moves down. When the first car reaches the OR gate, its kinetic energy is partially transferred to a lever mechanism, pushing it and allowing the car to pass through. However, as this lever pivots around its axis, it causes the second lever on the opposite side to move downward, blocking the track. Since the second lever does not have a pivot to rotate freely, it blocks the path of the other car, preventing it from passing.

AND Gate: The AND gate has two input and output tracks. As the cars move down the slope, their gravitational potential energy turns into kinetic energy. If only one car enters, it is stopped by a fixed lever, giving an output of 0. When two cars enter, the second activates a pivoting lever mechanism, which releases the first lever and lets the first car pass, meanwhile the second car gets blocked by a small wall that is built inside the lane. This shows the logical AND function: an output (1) occurs only when both inputs are active.

XOR Gate: The XOR gate consists of two lanes merging into one. As the cars roll down the slope, their potential energy turns into kinetic energy. If two cars enter, they collide and block each other, displaying an output of 0. If only one car passes, it moves through freely, giving an output of 1. This shows the XOR rule, where the output is 1 only when the inputs are different. However, for this to work, both cars have to enter at the same time. This problem has been solved by using a lever mechanism which is shown in the diagram of the full adder.

- **All measurements of mass, momentum, potential/kinetic energy, slope angle etc. have been calculated and explained in the next section.**

Connection to technology: In computers, electronic logic gates use electric signals to process information, and they can switch between two discrete states, where 0 represents “off” and 1 represents “on.” These signals travel through billions of electronic components called transistors, which act like switches that control the flow of electrical current. Our mechanical logic gates use this theory however with cars and levers instead of electricity. When a car is displayed in the output lanes, it represents a 1/on making the logic process visible and easier to understand.



We are currently working on building a full adder, which can process a maximum input of 1 + 1 + 1 (two bits plus a carry). A full adder is made from two half adders and an additional XOR gate to handle the carry output. We have already printed and tested the half adders. To complete our 4-bit binary adder, which can add numbers up to 15 + 15, we need to use eight full adders in total.

4. Funcionamiento y Resultados: observaciones y medidas.

The cars used in the project measure 40 mm × 30 mm, and the track was set on a 6° downward slope. When released, each car converts gravitational potential energy into kinetic energy. Using GPE = mgh, the energy at the top of the ramp is
GPE = 0.035(mass in kg) × 9.81(gravity on earth) × 0.210(height difference in m) = 0.072 J.
Assuming this becomes kinetic energy, the velocity is found from KE = ½mv², giving
v = √(2GPE/mass) = 2.03 m/s.
This produces a momentum of p = mv = 0.071 kg·m/s, which is transferred to the gate mechanisms to perform the logical operations.

The binary adder was tested with different input combinations over 70 trials, achieving 61 correct outputs, a success rate of 87%. The gates functioned reliably at this slope, but we observed that steeper slopes caused higher speeds and impact forces, increasing errors, while gentler slopes were slower but more accurate. Small timing differences between cars also affected performance, especially in the XOR gate, showing that synchronisation is essential. These results confirm that mechanical systems can effectively represent digital logic through controlled motion and energy transfer.

5. Conclusiones

Our project successfully demonstrated that logical operations can be represented using mechanical systems. The Hot Wheels binary calculator worked according to the expected function of the AND, OR, and XOR gates, accurately presenting binary addition.

Through this experiment, we proved that if data can be represented using two distinct states, 1 and 0, it is possible to perform binary calculations. In our model, the presence or absence of a car acts as those two states, showing that logic can exist in many physical forms, not just electronics.

This project highlights the connection between physics and computer science, as concepts such as energy transfer, motion, and collisions can be used to simulate digital logic. It also shows potential for educational applications, helping students visualise how computers process information. Future improvements could include adding a carry mechanism or expanding the system to handle more bits, creating a more complete mechanical binary adder.

6. Bibliografía

Es imprescindible citar las fuentes de las que se obtienen ideas o contenidos: libros, páginas web, vídeos de youtube, etc.
Más información en esta guía

https://www.youtube.com/watch?v=INEtYZqtjToç
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