# National University of Sciences and Technology (NUST), Balochistan Campus (NBC).

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Semester Project: **Digital Logic Design (EE-221)**

Project Title: **LEGO Mindstorms (SARKIAP-1 the transformer)**

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### Introduction:

In 1998, LEGO launched the Mindstorms construction kit. Mindstorms, a robotic invention system that revolutionized LEGO construction kits, grew out of the LEGO Company's 20-year collaboration with the Media Lab. With LEGO MINDSTORMS Robot Inventor (51515), kids gain essential STEM skills as they build, code and play with remote-control model robots and intelligent creations that shoot missiles, play ball, drive around and more! Lego Mindstorms is a hardware and software structure which develops programmable robots based on Lego building blocks. Each version includes computer Lego bricks, a set of modular sensors and motors, and Lego parts from the Technic line to create the mechanical systems.

**The following five essential qualities characterize robots and features:**

**Intelligence**.

Human intelligence is derived from the elaborate and interconnected network of neurons within the human brain.

**Sense Perception**.

Becoming aware of something via the senses.

**Dexterity**.

Adroitness in using the hands.

**Power**.

Possession of controlling influence.

**Independence**.

The state of being able to support oneself without help from others.

### NEW LEGO MINDSTORMS ROBOT INVENTOR 51515:

It had been more than 7 years since the launch of the well-known and appreciated LEGO Mindstorms EV3, which is available on Robot-Advance as LEGO for the home or LEGO Education for the classrooms. A new wind that will strongly appeal to all LEGO and robotics enthusiasts, who with this new LEGO Mindstorms Robot Inventor 51515, will be able to let their imagination run wild and further develop their building, coding, robotics and much more skills. The most attentive among you will have noticed the "Retiring Soon" label on the LEGO Mindstorms EV3 (Home Edition) of the LEGO Shop, which will therefore be replaced by the end of 2020 by the LEGO Mindstorms Robot Inventor 51515. The new Robot Inventor whose box you can see in the picture below will be a box of 949 pieces that should be according to LEGO proposed to the general public at the beginning of the 4th quarter 2020 for a price of 359.99€ which Pakistani 78740.031903139 Rupees, only a few euros less than the LEGO Mindstorms EV3 Home Edition.

Its big strength is that it allows you with its content to create different robots that will each have different functionalities and features. Be careful, you will only be able to build the robots one by one with the 949 parts and therefore you will have to separate the old from the new LEGO robot to create a new LEGO robot. A rather very intelligent and advantageous system that will give the LEGO Mindstorms Robot Inventor a very long life span and a stronger desire for discovery.

This new Mindstorms 51515 will include a Rechargeable Smart Hub that you first saw in the newest LEGO Education Spike Prime and that opens up a lot of possibilities in terms of connections and components:

- Bluetooth connection
- Gyroscopes
- Accelerometers
- Engines
- Sensors (Colors, ultrasounds...)

All these elements that will allow the remote control of the robot and the coding of very interesting functionalities.

**Robots to create with LEGO Mindstorms Robot Inventor:**

The five main LEGO Mindstorms robots to be created are visible on the front of the new box but here is some additional information.

- **Blast**: Action robot, it can shoot or make its way through obstacles and grasp objects. The creators will be the ultimate commanders, programming it to analyze its environment and shoot darts if it detects danger. Perfect for guarding your room!
- **Charlie:** Eccentric auxiliary robot that can give high fives, dance, play drums, give small gifts and charm friends with his smile.
- **Tricky:** The sports robot of the gang, the ultimate athlete. Code it to complete the perfect slam dunk or master a multitude of sports such as basketball, bowling, football or others, the list is long.
- **Gelo:** Four-legged robot. Its unique mechanism allows it to walk, avoid obstacles and even perform tricks.

- **MVP:** Modular vehicle platform. Create and code your own remote control and build the MVP into a buggy, crane, shooting turret or even a truck that will pick up the LEGO bricks left behind by other robots.
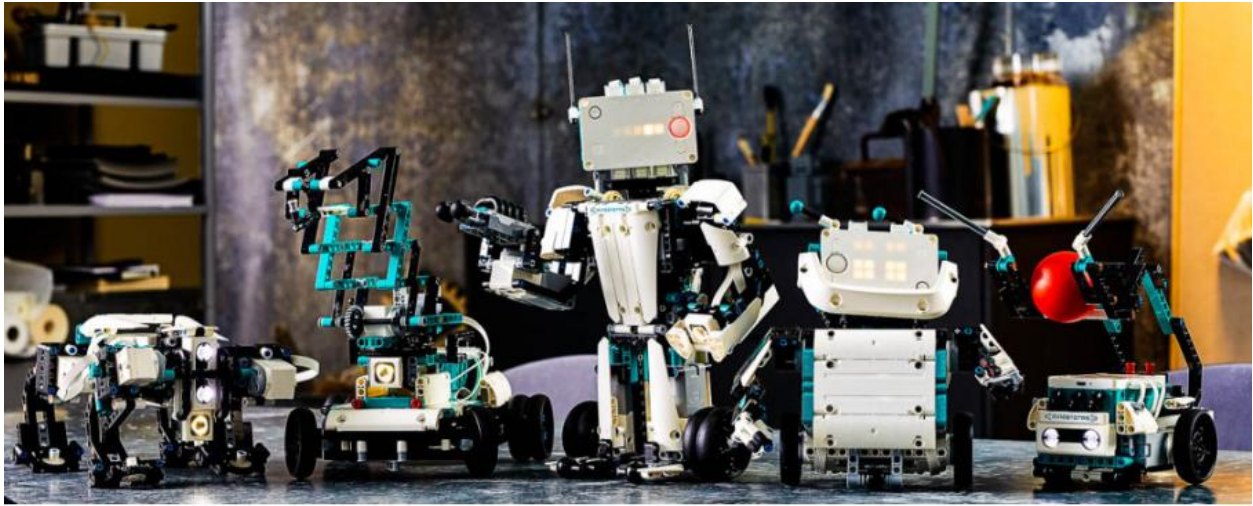


**Here are some additional LEGO Mindstorms robots which can be built through this set.**

**Baseball batter:** The Baseball Batter is a simple contraption that will help you take the first steps in robot programming. The picture is shown below.
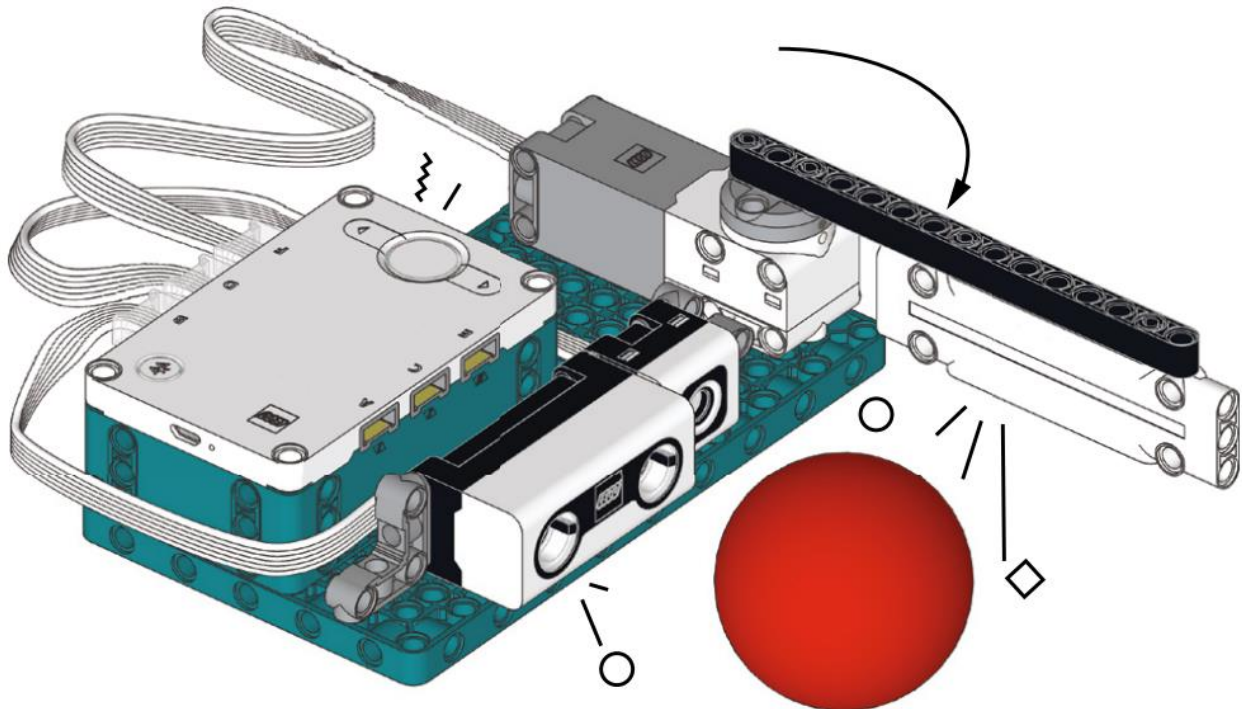


**The Gobbler:** A desktop pal that swallows and crumples strips of paper you put in its mouth. Write down troubling thoughts or things that make you feel sad. Then let the Gobbler do its job: gobble them, crease them, crumple them, tear them, and shred them. You might feel a bit better afterward**.** As shown in the figure below.
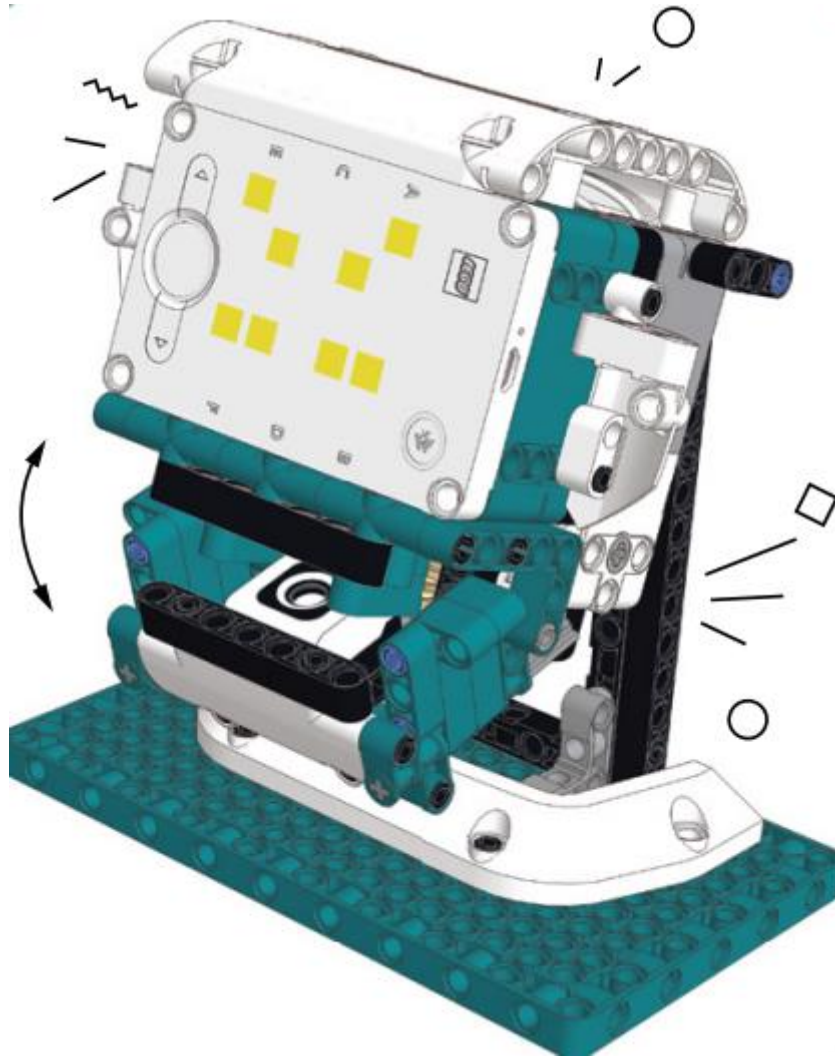
**Shelly the Turtle:** LEGO MINDSTORMS sets aren't just for building alien robots and remote-control vehicles. With the same LEGO elements, you can also build cute creatures like Shelly, a pet turtle you can pamper, feed, and take for a walk. But be careful—she's very shy! Even a gentle tap on her back might cause her to hide her head in her shell and shiver with fear. Shelly the Turtle is given below.
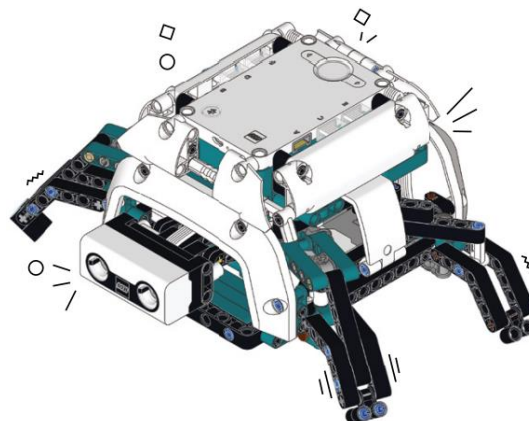
**Whac-a-mole!** The LEGO MINDSTORMS set isn't just a toy. It's a toolbox that you can use creatively, even to make your own games. A robot based on a popular arcade game (also called Mole Buster) invented by Kazuo Yamada in the 1970s. As you build and program this game, you'll discover how to use the built-in rotation sensor of the LEGO motors to sense the moles being hit. You'll also learn how to use the Hub's timer to measure a player's reaction time and how to work with several variables within the same program. Below is the Whac-a-mole!
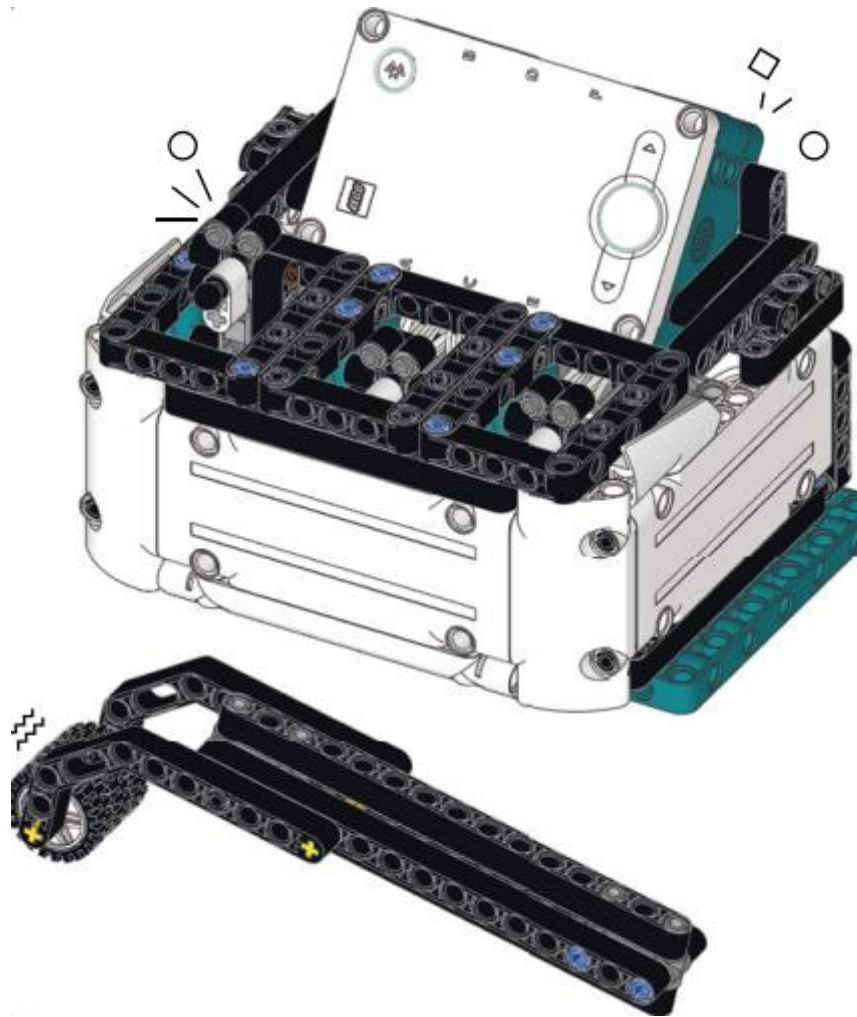


**Pinball:** A fully functional pinball game complete with bumpers that use the LEGO motors' built-in rotation sensors to sense even the slightest contact with the ball. As you program Pinball, you'll learn how to use lists, which are a special kind of variable. You'll also learn how to display two-digit numbers on the Hub LED matrix display and how to change the intensity of the Distance Sensor lights by using text strings. The picture is shown below. This pinball machine is a super fun and engaging game, built inside the Robot Inventor box lid.
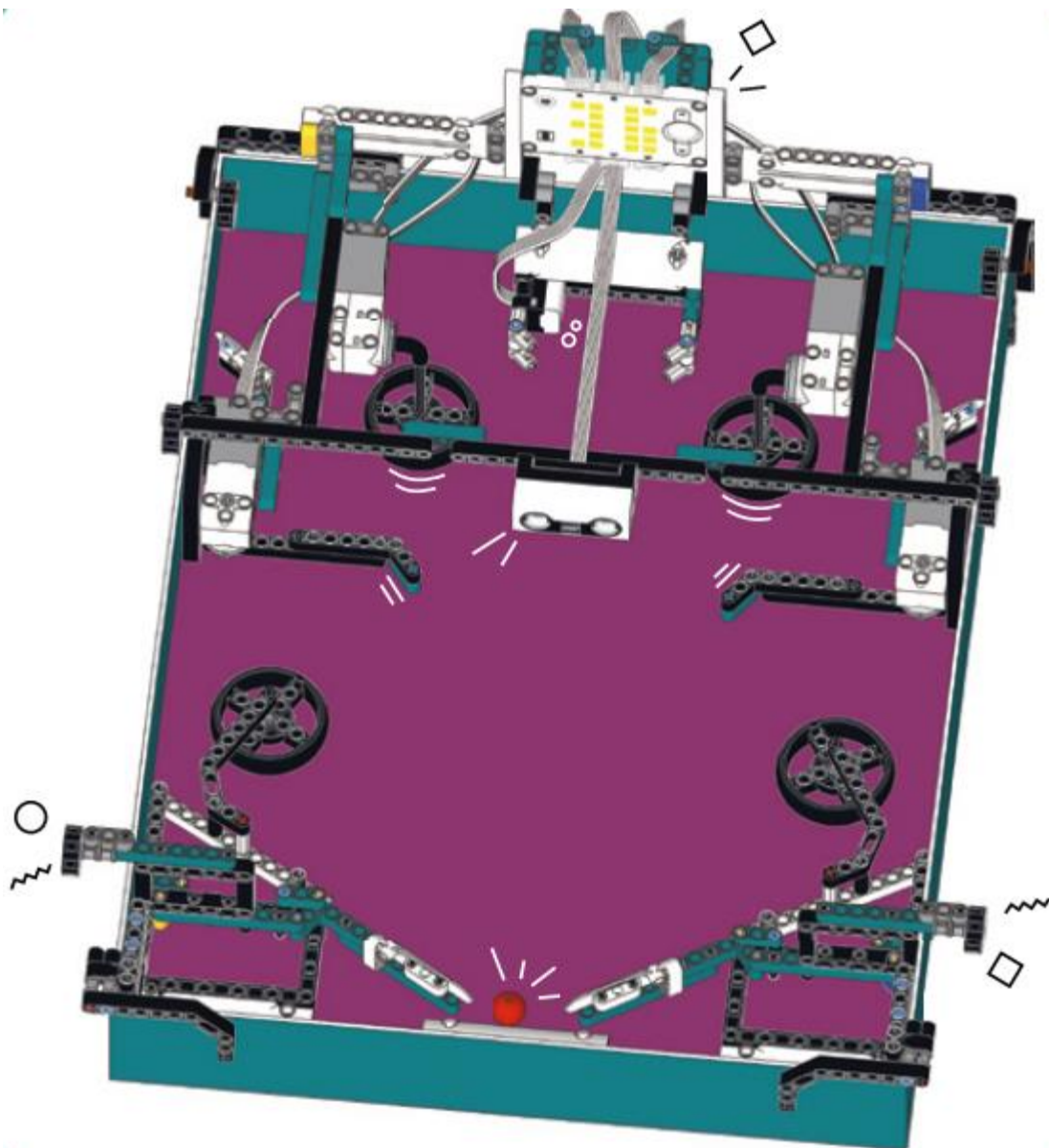
**Guitar:** The Robot Inventor set includes large elements and frames that allow you to quickly build big, strong models. To prove it, we'll create a working electric guitar. The Guitar is three-quarter size, or 75 percent as long as a real guitar. Instead of having strings that you pluck to make sounds, it'll use the Color Sensor and Distance Sensor to respond to your hand movements, so you can play solos and chords even if you aren't a trained musician. While building this guitar, you'll learn how to make large yet sturdy structures, like the Guitar's body and neck. While making the programs, you'll see how to use math to transform sensor readings into a different range of values. You'll also learn how to store a lot of numeric data in the items of a list and how to retrieve pieces of that data by using text manipulation blocks.

You can play solos and chords on this three-quarter-size LEGO electric guitar, even if you've never touched a real guitar!
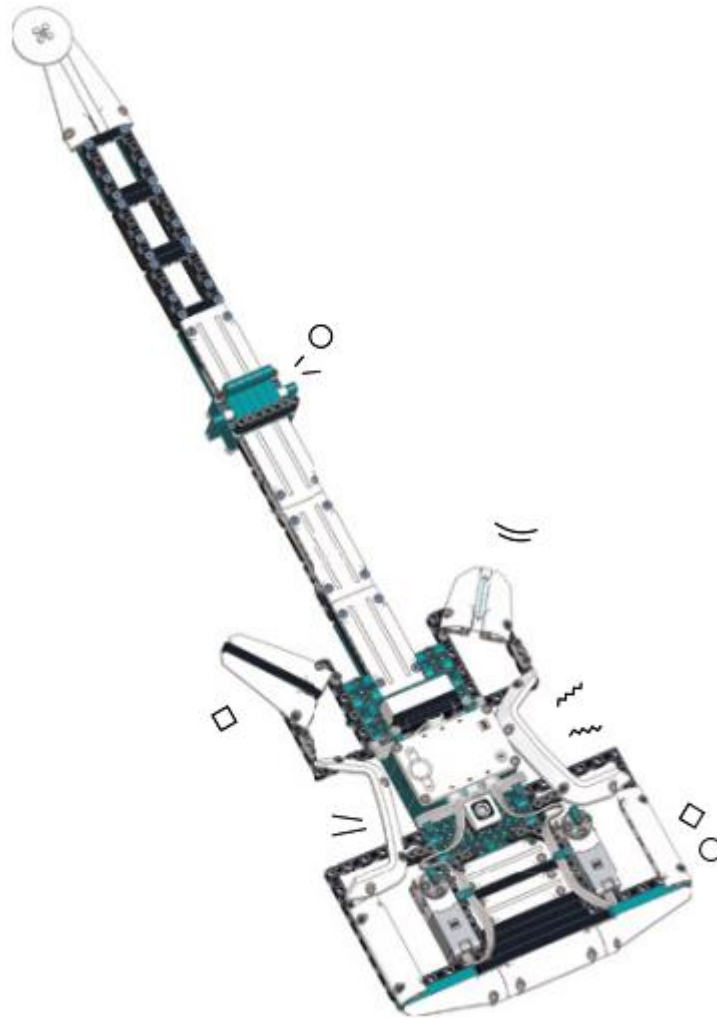
**Hence,** there are more many other LEGO Mindstorms robots which can be built by this set.

**LEGO Mindstorms Robot Inventor Mobile Application:**

This new LEGO Mindstorms Robot Inventor will come with a dedicated and free mobile application. Those who would be afraid to go for it should be reassured, the coding via the application has been adapted to all levels:

- Visual coding for beginners with a Scratch-based drag and drop system.
- Textual coding for the more advanced and direct writing of lines of code and Python support.

The mobile application LEGO Robot Inventor will provide access to more than 50 activities to explore but also to diversify the remote controls for robot control:

- Ability to create custom digital remote controls.
- Support for existing Bluetooth controllers such as PS4 or Xbox one.

The mobile application's digital remote control generator will work on all Powered Up assemblies to tune the controllers with the construction and components. At the launch of the new LEGO Mindstorms, the mobile application will be operational on Windows 10, Mac, iOS, Android tablets and smartphones, and a

few other specific devices. Building and coding instructions for each of the five models will only be available digitally via the application and not on paper in the box.

With Robot Inventor, LEGO has completely switched to the LEGO Power Functions 2.0 system with an identical interface for the:

- LEGO Powered Up
- LEGO Control Plus
- LEGO Boost
- LEGO Spike PRIME
- LEGO Mindstorms avec Robot Inventor

Note that the new LEGO Power Functions 2.0 hardware is not compatible with the EV3.

**New LEGO Mindstorms elements:**

New features include the new Intelligent Hub, an advanced yet simple to use hub with 6 input/output ports to connect various sensors and motors. The Hub can also be used with LEGO Technic and System components to create fun and interactive robots.

- LED array $5 \times 5$
- Bluetooth connectivity
- 6-axis gyroscope / accelerometer
- Includes a micro USB port for connectivity with compatible devices
- Speaker
- Rechargeable lithium-ion battery included

Below are other elements that you can find in the LEGO Mindstorms Robot inventor 51515:

- **Color Sensor:** capable of differentiating eight colors and measures reflected and ambient light from darkness/sunlight
- **Distance Sensor:** Detects obstacles, programmable LED "eyes" and built-in 6-pin adapter for third-party sensors, cards and do-it-yourself hardware.
- **4x medium-angular motors**, integrated rotation sensor with absolute positioning
- **New base plate** 7 x 11
- **New black wheels**
- **New executives**

# SARKIAP-1 THE TRANSFORMER
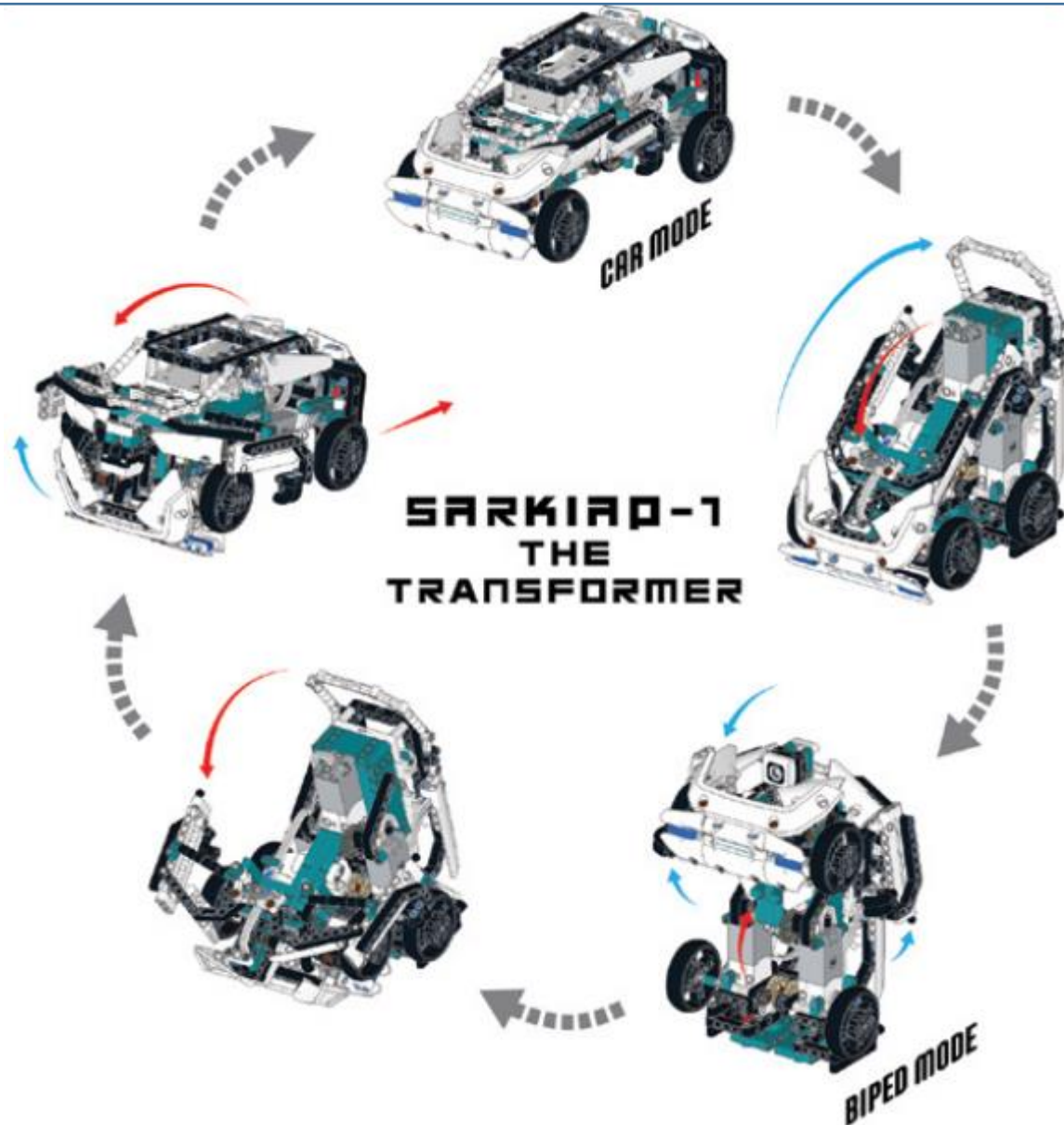


SARKIAP-1 is a remote-control robot that can change from a car to a biped and back.

In this project, we have made a transformer which are robots from another planet that can hide on Earth by transforming into vehicles. A remote-control car that can transform into a humanoid robot that can walk. It really walks, not just roll around on the same wheels it uses as a car. The Transformers are a species of sentient, living robotic beings (mostly) originating from the distant machine world of Cyber Tron. The stories of their lives, their histories, and most especially their wars have been chronicled across many different continuities in the vast multiverse. Transformers are called, Autobots. (also known as Cybertrons in Japan) are the heroes in the Transformers toy line and related spin-off comics and cartoons.

We have used the **Hub** which is its brain, hold the button on the Powered up Hub down for approximately > 5 seconds and it will begin to blink rapidly. Release the button and it will disconnect.

The hub also shuts down automatically when the app is closed. This advanced control unit features an integrated tilt sensor, as well as 6 input/output ports to program and control LEGO Powered Up sensors, motors and lights. The Hub is a computer, a programmable LEGO brick for making your robots work. You can use the Hub to run programs, instructions you'll write for the robots you'll build. The programs tell the Hub how to control the motors and sensors, which you can plug into the Hub's six ports (three on each side). The Hub is smart enough to know what kind of motor or sensor is connected to each port, without needing to be told. The Hub has a 5×5 matrix display, made of five rows and columns of light-emitting diodes (LEDs), and a built-in speaker. It has a six-axis inertial measurement unit (IMU) consisting of a three-axis accelerometer and three-axis gyroscope. An IMU is the same kind of device that tells a smartphone or tablet which way is up, and you can similarly use the Hub's IMU to detect how the Hub is rotating or oriented in space. The Hub also has three buttons for menu navigation and one button to enable Bluetooth pairing. You can connect the Hub to other devices for programming and remote control using USB or Bluetooth. Last but not least, the Hub has a battery that can be recharged by attaching the Hub to any USB power supply with the included USB-to-micro USB cable. That's really handy and eco-friendly!

Moreover, we have used three **Motors**, the first two for the movement of the feet, last one which is the backbone of it, used to transfer it from the humanoid form into biped one. The three Medium Motors are a pleasure to work with, thanks to their compact shape and many mounting holes. They're servomotors, meaning you can turn them to specific positions and control their speed. Each motor has a zero-position, marked on the motor body with a circle. The motor's built-in rotation sensor measures the position of the motor shaft (the part of the motor that spins) relative to that zero-position. This handy feature means you don't need to bring the motor to an initial known position.

Besides, we have used a **Color Sensor** can shine a light from its LED onto an object placed about 2 centimeters (a little less than 1 inch) in front of it and measure the percentage of light reflected by that object. This kind of grayscale measurement is useful, for example, to detect the edge of a black line on a white surface. The sensor can also detect the color of an object, returning a number that corresponds to one of the LEGO colors (white, blue, black, green, yellow, red, teal, violet, or no color).

**Main Buildings:**

- Right Leg Subassembly
- Left Leg Subassembly
- Right Foot Subassembly
- Left Foot Subassembly
- Torso Subassembly
- Shoulders Subassembly
- Transformer Subassembly
- Windscreen Subassembly
- Front Bumper Subassembly

**Right Leg Subassembly and Left Leg Subassembly:**

The driving gear (the one on the motor shaft) has 20 teeth, and the driven gear (on the axle the wheel will be mounted on later) has 12 teeth. The gear ratio is 12:20 = 3:5. That means that the wheels make five turns for every three turns of the motor shaft. This gearing increases the speed of the wheel with respect to the motor speed and reverses the direction of rotation right leg.
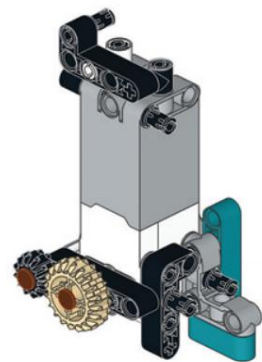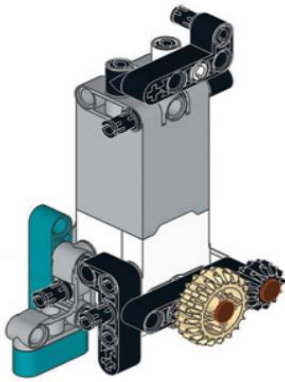
**Right Foot Subassembly and Left Foot Subassembly:**

The most common form of misassemble is the swapping of two similar parts from left to right, such as feet, forearms, door kibble etc., and/or having parts attached backwards.
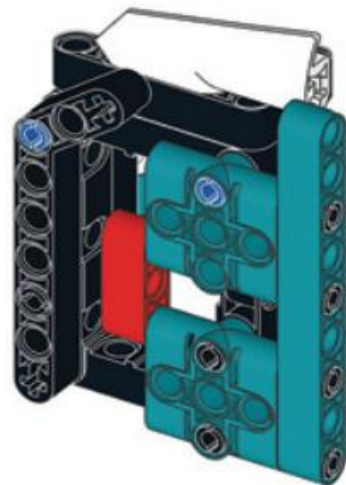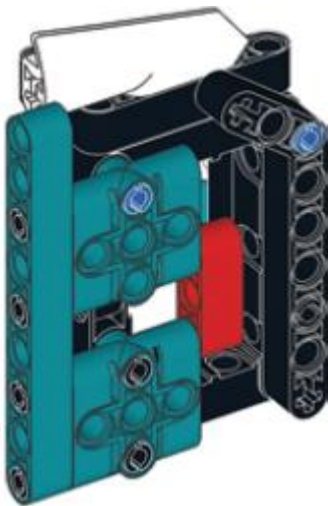


Insert the blue pin of the ankle joiner in the marked hole of the shaft. The motor shaft works as a crank. Its rotation is transformed into a back-and-forth motion of the foot. In one turn of the motor, first the ankle is bent so that the weight of the robot shifts onto the foot, lifting the other foot from the ground. Then the foot slides backward, moving the whole robot forward. Finally, the ankle is bent to put the other foot on the ground again. The same happens for the other foot but offset by half a turn, as shown below.
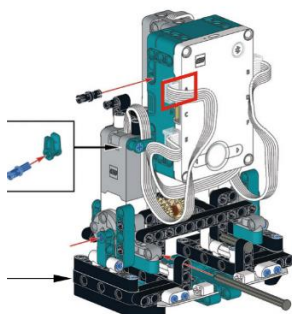


Insert the blue pin of the ankle joiner in the marked hole of the shaft.
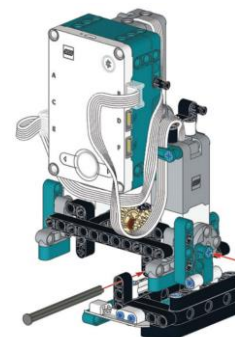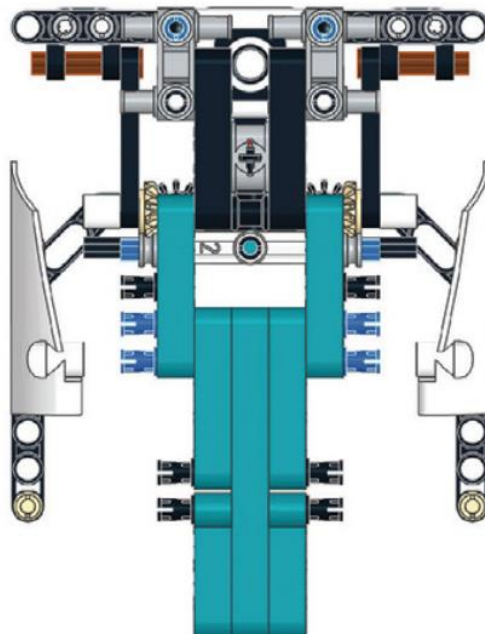
**Torso Subassembly:**
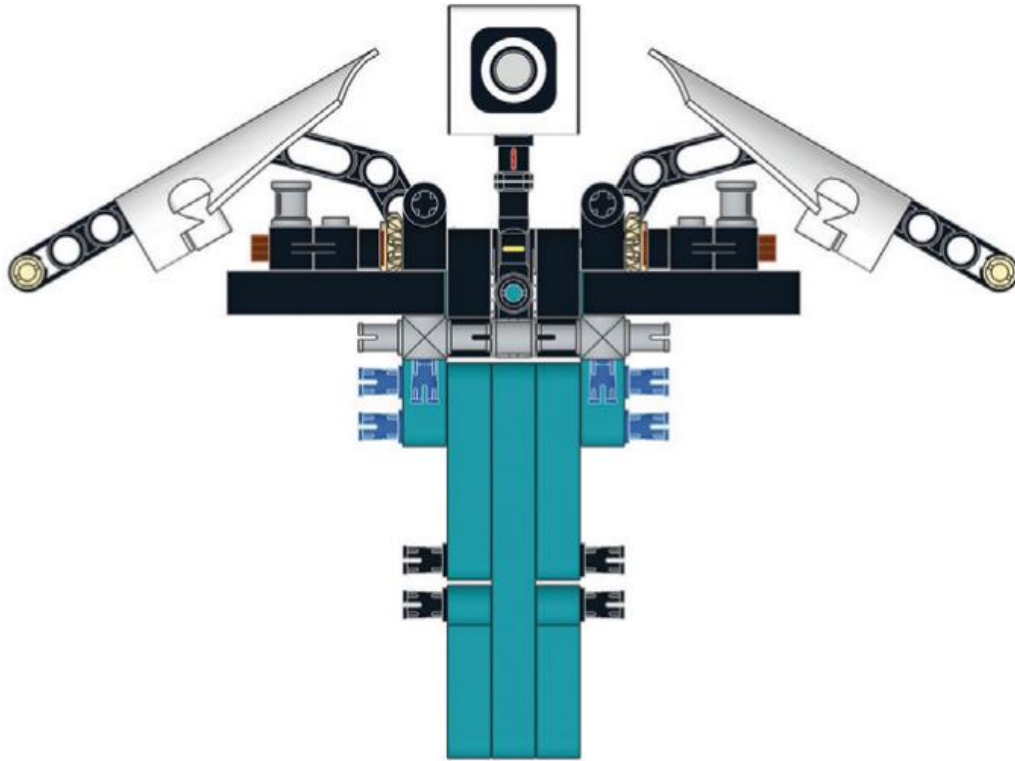


Here we made sure the arms are symmetrically aligned and angled as shown here when you attach them. This is how the arms will appear when the Transformer is in biped mode (chest is folded down).

**Shoulders Subassembly:**

We aligned the arms correctly before engaging the gear teeth. The arms are symmetrically aligned and angled as shown here when you attach them. This is how the arms will appear when the Transformer is in biped mode (chest is folded down). To check that we assembled the arms correctly, make sure the arms are parallel to the teal pieces of the torso when the Transformer is in car mode (chest is unfolded).

**Transformer Subassembly:**
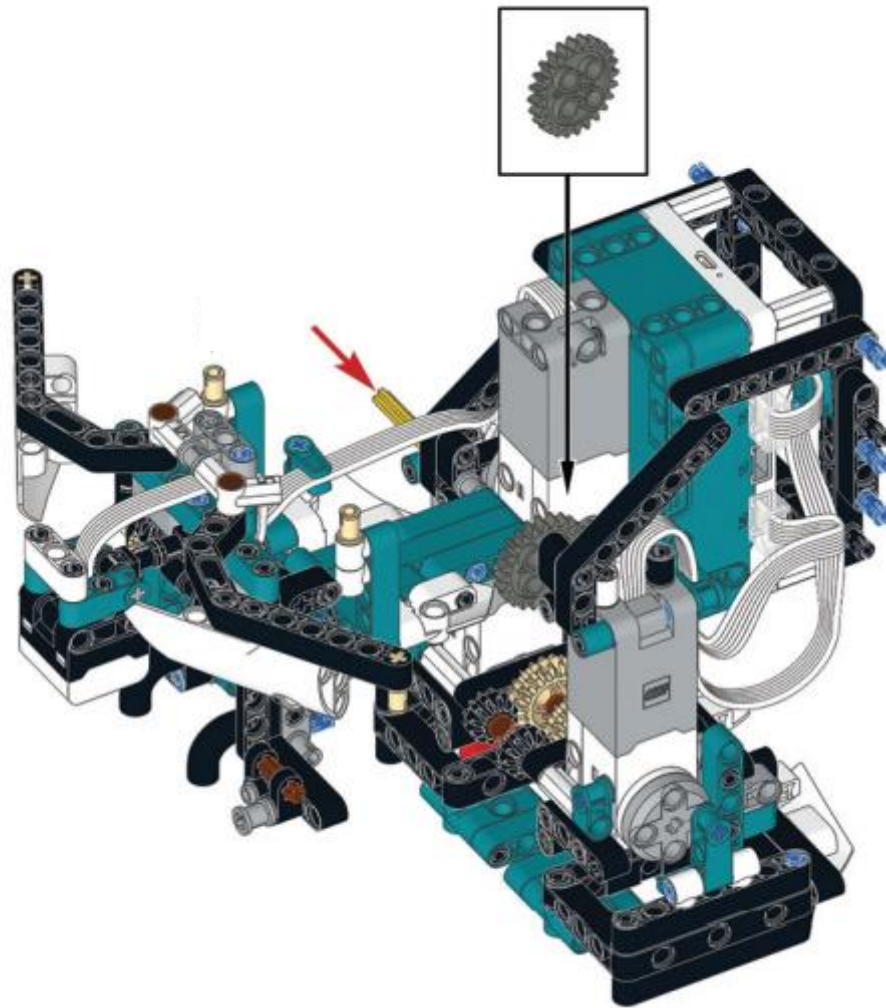


The driving gear attached to the motor shaft has 8 teeth, and the driven gear attached to the torso axle has 24 teeth. The gear ratio is 24:8 = 3:1, which means that the torso axle will spin three times slower than the motor shaft. This gearing makes the motor's torque three times stronger. Torque is a twisting force that, when applied to an object, makes it rotate. In this case, the gears allow the motor to lift the torso with three times less effort than if the motor were driving the torso axle directly.

**Windscreen Subassembly:**

The driving gear attached to the motor shaft has 8 teeth, and the driven gear attached to the torso axle has 24 teeth. The gear ratio is 24:8 = 3:1, which means that the torso axle will spin three times slower than the motor shaft. This gearing makes the motor's torque three times stronger. Torque is a twisting force that, when applied to an object, makes it rotate. In this case, the gears allow the motor to lift the

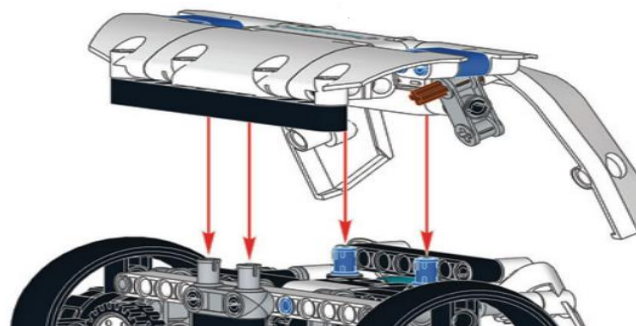torso with three times less effort than if the motor were driving the torso axle directly. The small wheels prevent the main wheels from shaking when the robot is walking.
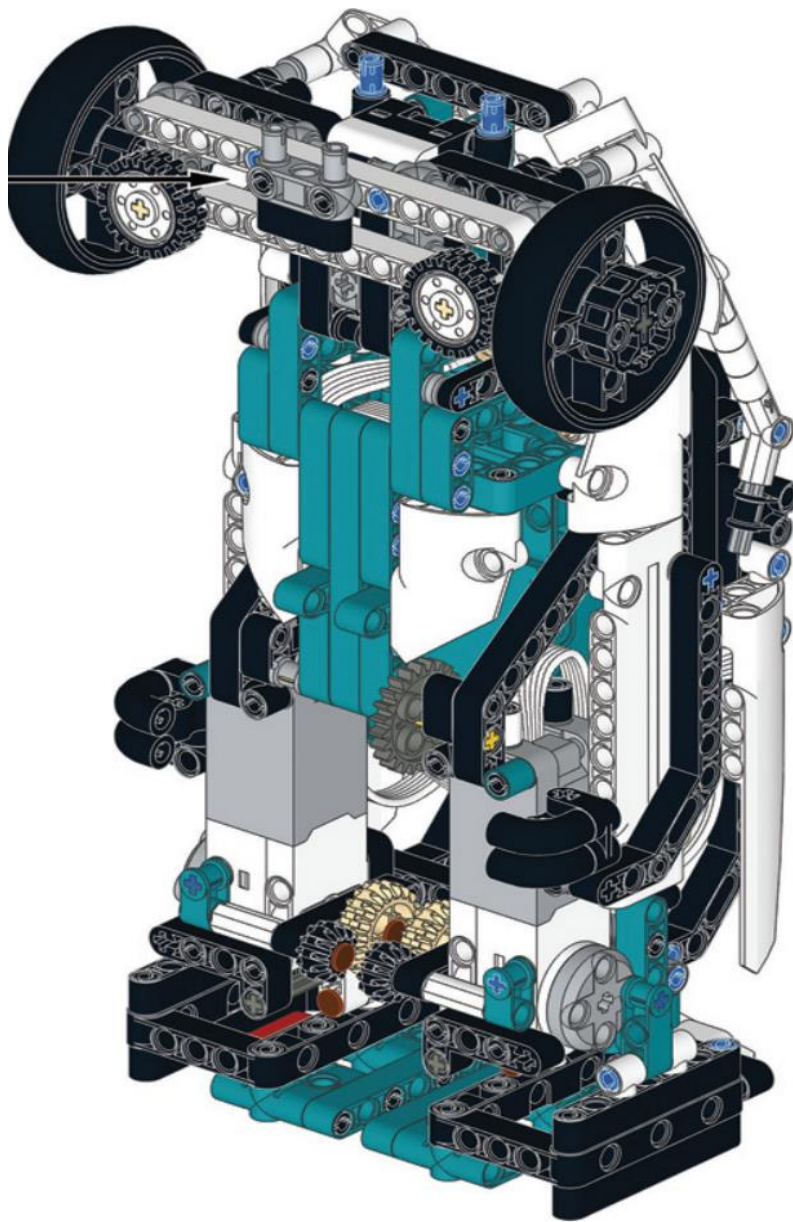
**Front Bumper Subassembly:**

**Programming:**

The free LEGO® MINDSTORMS® Robot Inventor coding app for kids uses coding language based on Scratch and supports Python for more advanced coders. The application works across PC Windows 10 + mac OS, iOS and Android tablets and smartphones as well as specific Fire OS devices.

The complete programming done in our project is shown in the picture below:



**Applications:**

- For use with the LEGO MINDSTORMS Robot Inventor (51515) set launched in 2020, this companion app has everything you need to build Charlie, Tricky, Blast, M.V.P, Gelo and many more, each with their own unique abilities. Then get ready to code and play your way through 50+ challenging activities.
- With LEGO MINDSTORMS Robot Inventor (51515), kids gain essential STEM skills as they build, code and play with remote-control model robots and intelligent creations that shoot missiles, play ball, drive around and more!
- Best Overall Robotics Kits, Editor's Choice: LEGO Mindstorms Robot Inventor Building Set 51515. LEGO Mindstorms Robot Inventor Building Set 51515 is our editor's pick for the top LEGO Robot kit that stimulates middle and high schoolers' interest in STEM subjects.
- An Integrated development environment targeted towards students that is used to program and control LEGO NXT, VEX, RCX and Arduino robots using a programming language based on the C programming language. ROBOTC gives the ability to use a text-based language based on the C language. An Integrated development environment targeted towards students that is used to

program and control LEGO NXT, VEX, RCX and Arduino robots using a programming language based on the C programming language. ROBOTC gives the ability to use a text-based language based on the C languageIt includes built-in debugger tools, as well as (but not limited to) code templates, Math/Trig operations (sin, cos, tan, asin, acos... etc.), user-friendly auto-complete function built into the interface, built-in sample programs. This deserves a special note for its debugging tool. For any developer, you will know how important it is to have a good debugging tool. Among all other robotics programming languages which support Mindstorms platform, RobotC's debugging environment does deserve a special note; although it is not free.

- Mindstorms kits are also sold and used as an educational tool, originally through a partnership between Lego and the MIT Media Laboratory. The educational version of the products is called Mindstorms for Schools or Mindstorms Education, and later versions come with the ROBOLAB GUI-based programming software, developed at Tufts University using the National Instruments LabVIEW as an engine.

**Conclusion:**

- It took us quite a lot of time to figure out how to make a biped walking robot transforming into a real car with steering, using just one motor to transform, and another force that comes for free: GRAVITY.
- The robot can be remote controlled using the LEGO MINDSTORMS App.
- This is the first LEGO robot ever made that can actually walk (and not just roll on wheels) when in humanoid mode, and drive and steer when in car mode.
- We used three motors in total, although the LEGO MINDSTORMS Robot Inventor set has four of them.

**Future Use:**

- We would redesign a new transformer car that features the same core mechanism but can be in a different form.
- We can bring many changes in its programming for example can give some logical instructions for performing many other tasks.
- We would control it by ps4.
- We can complete and advance it to talk, play games, and perform a variety of other programmable tasks.
- Most importantly, a digital clock, this high-tech digital clock will keep the classroom running right on time.

**References:**

- The LEGO Mindstorms Robot inventor Activity Book.
- Wikipedia (https://en.wikipedia.org/wiki/Lego_Mindstorms#Use_in_education).
- LEGO's official site (https://www.lego.com/en-sg/aboutus/news/2020/june/lego-mindstorms-robot-inventor/#:~:text=The%20free%20LEGO%C2%AE%20MINDSTORMS,as%20specific%20Fire%20OS%20devices.)
- Robot Advance (https://www.robot-advance.com/EN/actualite-new-lego-mindstorms-robot-inventor-51515-213.htm)
- The brothers brick (https://www.brothers-brick.com/2020/10/10/the-next-generation-of-lego-robotics-mindstorms-51515-robot-inventor-review/lego-mindstorms-51515-reivew-13/)

- Looper (https://www.looper.com/186277/transformers-reboot-in-the-works-with-two-separate-movies/)
- Eurobricks uniting Technic Fan around the World (https://www.eurobricks.com/forum/index.php?/forums/topic/188499-tc21-technic-transforming-vehicle-sarkiap-1/).
- YouTube Channel (https://www.youtube.com/watch?v=oRBfjK-qeXE&list=PL0-84-yl1fUkall6a14nqzXpG79-RgI1F)

THE END!