Introduction to LEGO® MINDSTORMS® NXT Hardware

LEGO® MINDSTORMS® NXT is the next-generation of robotic construction and programming kits offered by the LEGO Group. The kit includes a microcomputer module (that can be programmed offline by a desktop or laptop computer), several DC motors, and a variety of sensors that can be combined with standard LEGO® components to create moving, "intelligent" machines. Introduced in August 2006, we will be working with the version designed for the education market, LEGO® MINDSTORMS® Education NXT. We will also be using the Education Resource Kit, a supplementary set of various LEGO® construction components. If you are familiar with the previous MINDSTORMS®, you will notice a number of significant differences between the two.

NXT Components

Figure 1 below shows the main electromechanical components of the NXT kit. In the center of the figure is the NXT "brick," the brain of the MINDSTORMS® system. This component contains a 32-bit microcontroller into which programs can be downloaded through a USB port or via Bluetooth®. The brick has four ports for sensor input (labeled 1, 2, 3, and 4) and three output ports (labeled A, B, and C) for driving the motors and other output devices (e.g., lamps). There is an LCD screen for information display, and four buttons that allow interaction with the onboard file system and other utilities. The brick requires six AA batteries; fortunately, the education version comes with a rechargeable battery pack.

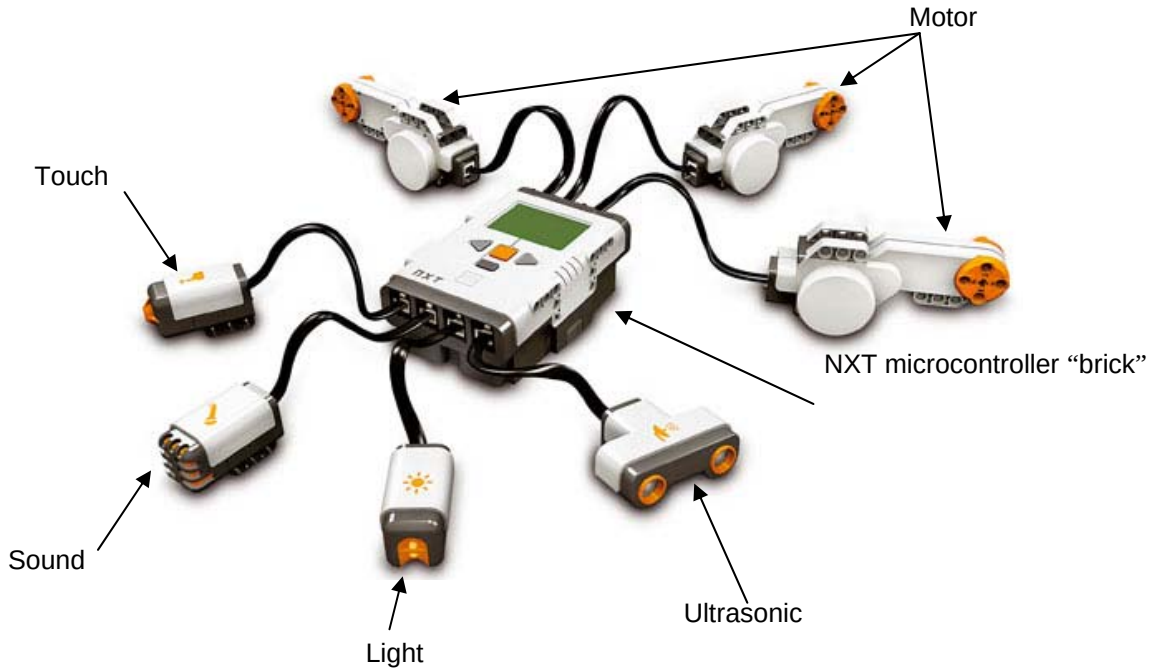


Figure 1. NXT controller, motors, and sensors.

Figure 2 shows the internal construction of the NXT motor. This is a type of DC motor called a “servomotor” that uses feedback to precisely control the rotation of the motor shaft. The shaft encoder labeled in the figure is a rotation sensor that enables this feedback mechanism. Notice the integrated gear train in the motor. (Why are there so many gears?) As we will see, the NXT programming environment allows program control of the motor power and number of rotations of the output shaft. The program can also read the value of the rotation sensor if desired.

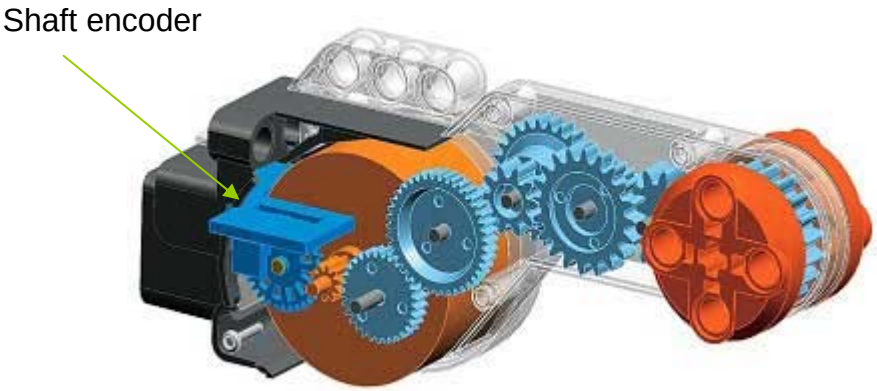
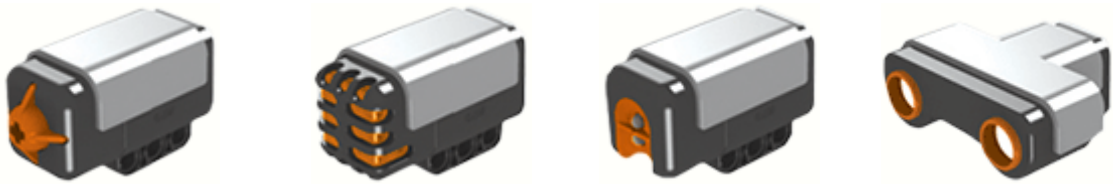


Figure 2. NXT motor internals (http://www.philohome.com/nxtmotor/nxtmotor.htm, modified).

Figure 3(a) shows the NXT touch sensor. This sensor provides a signal indicating whether the button is pushed in or released. The NXT programming environment also provides the capability of your program to respond to a “bump” (push followed by release). Notice the

cross-shaped hole at the end of the button; this feature allows you to insert a LEGO® cross-axle into the button to effectively extend the length of the button.



(a) Touch sensor (b) Sound sensor (c) Light sensor (d) Ultrasonic sensor

Figure 3. NXT touch sensor (http://mindstorms.lego.com/Overview/).

Figure 3(b) shows the NXT sound sensor. This sensor is essentially a microphone that detects sound pressure levels up to 90 dB. The sound pressure level is displayed in the program as a percentage of this maximum level.

Figure 3(c) is the light sensor. This sensor detects light intensity, not color. The light sensor displays the intensity as percentage of the maximum intensity level. The light sensor has an integrated LED to provide a light source for low-light conditions.

Figure 3(d) shows the ultrasonic sensor. This sensor is used to measures distances. Notice the two ports on the front of the sensor. One of these is an ultrasonic emitter, and the other is a detector. This sensor measures distances by determining the time it takes for an emitted sound wave to bounce off an object and return to the detector. This is the same principle used in sonar and radar devices (although radar uses radio waves). The sensor reports distances in centimeters and inches.

LEGO® Construction Components

The LEGO® construction components included in the NXT kit use the TECHNIC® approach to building structures. This construction style is based on beams connected with axles and pegs. This is also called “studless construction by some because the TECHNIC® components lack the characteristic studs of classic LEGO® bricks. Although studless construction requires a little more forethought and planning, the resulting structures are generally stronger and more robust than stacked brick structures. The NXT kit actually includes a mix of TECHNIC® and studded components, as outlined below.

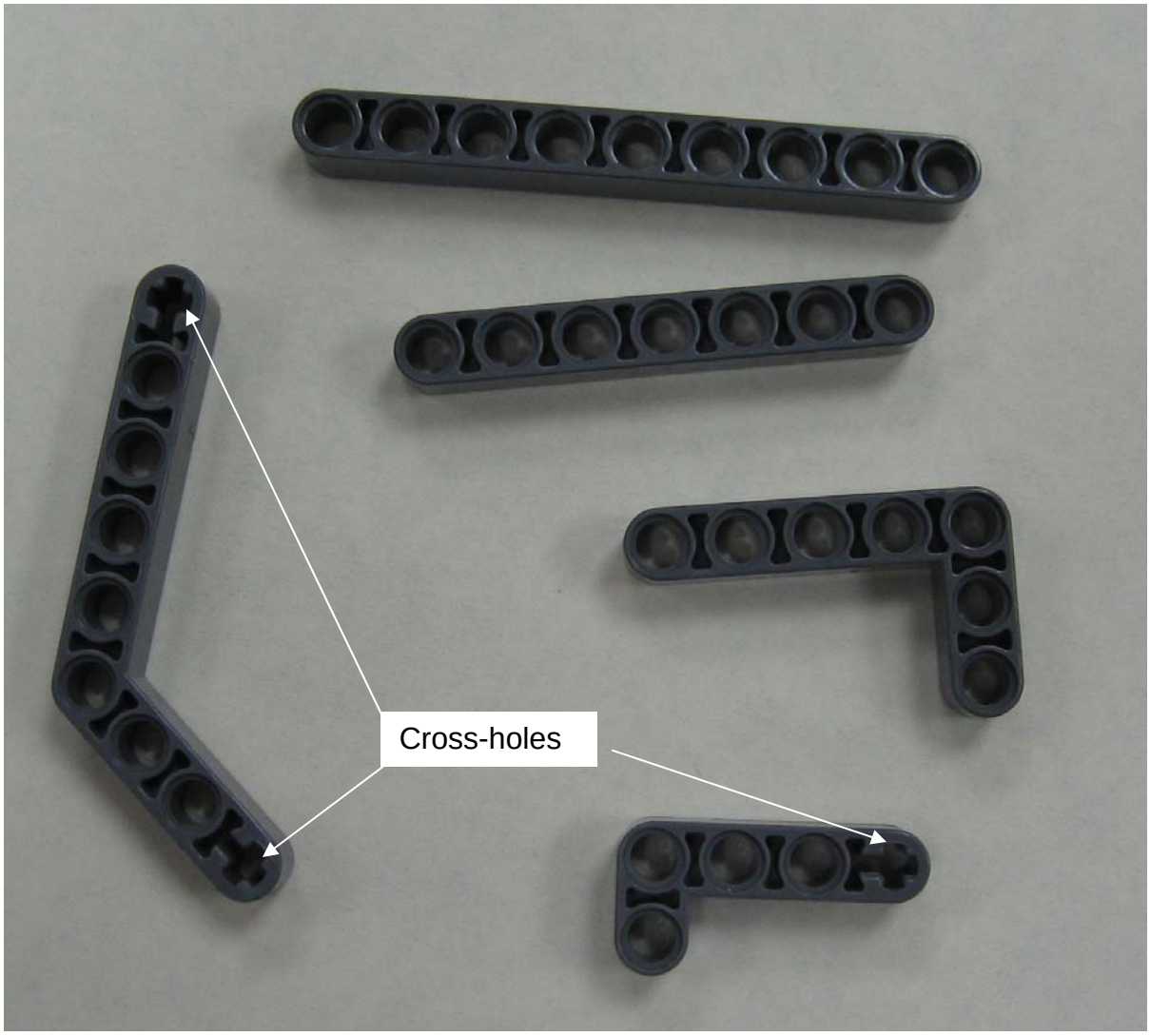


Figure 4. TECHNIC® beams from the NXT kit.

Figure 4 shows a collection of beams from the NXT kit. Notice that these beams have no studs. Some are straight, and others are angled. Also, as shown in the figure, some beams have holes that are cross shaped rather than round. These holes accept cross-axles (described below) that can be connected to the beams but are not allowed to rotate.

Contrast these beams with the studded components shown in Figure 5. This is a collection of studded beams, bricks, and plates that are included in the NXT kit.

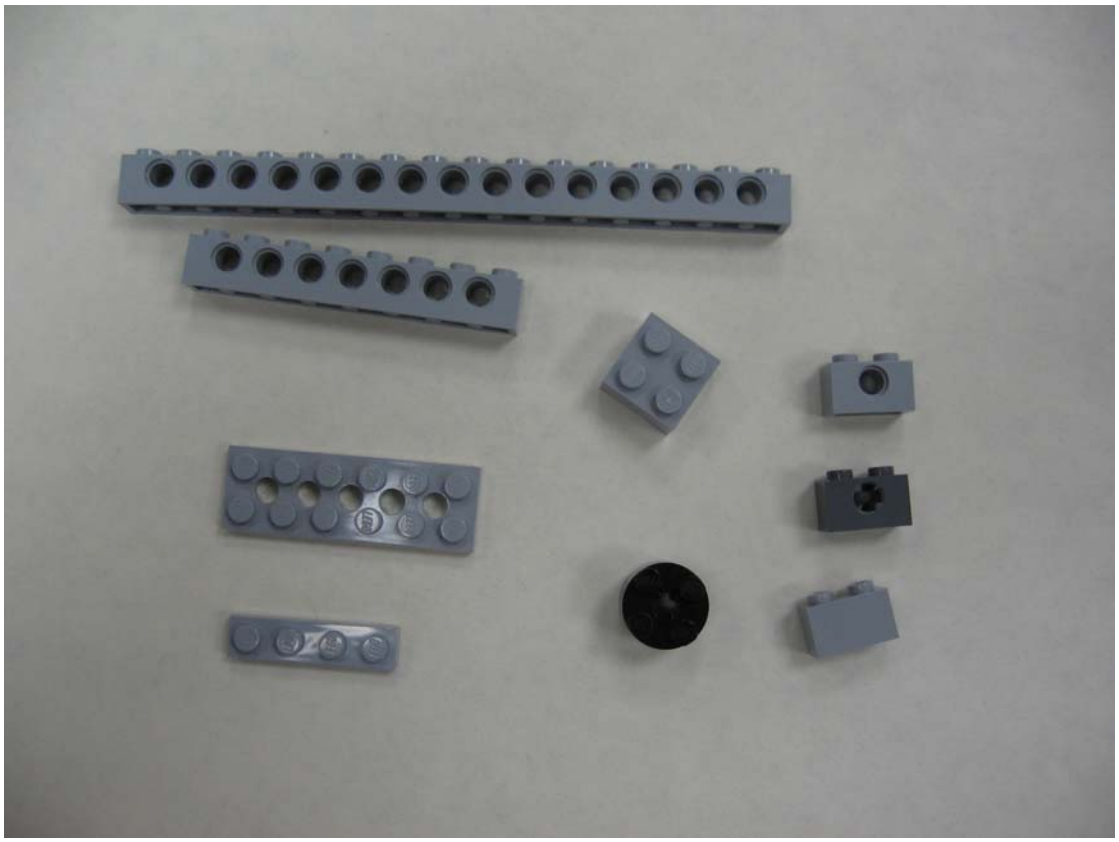


Figure 5. Studded components included in the NXT kit.

Figure 6 shows a variety of pegs included in the NXT kit. These pegs have at least one end that can be inserted in the round holes of beams. The two pegs on the right each have a crossed end that can be inserted into a cross-hole in a beam. The other end of these pegs fits into a round beam hole. This allows the beam connected by its round hole to rotate about the peg. The different colors denote how easy it is to rotate the peg in a hole. The black pegs exhibit more friction when rotated than the gray pegs. The blue cross-peg produces more friction than the tan cross-peg.

Figure 6. Pegs from NXT kit.

Figure 7 shows a variety of cross-axles from the NXT kit. All of these cross-axles have a crossed shape to fit in cross-holes in beams, wheels, gears, pulleys, and bushings. The cross-axles come in various lengths. The black cross-axles have even lengths, while the gray cross-axles have odd lengths. The length of a cross-axle is in units of studs or beam holes. This is shown in Figure 8, which shows a 5 unit gray cross-axle and a 12 unit black beam.

Figure 7. Cross-axles from the NXT kit.

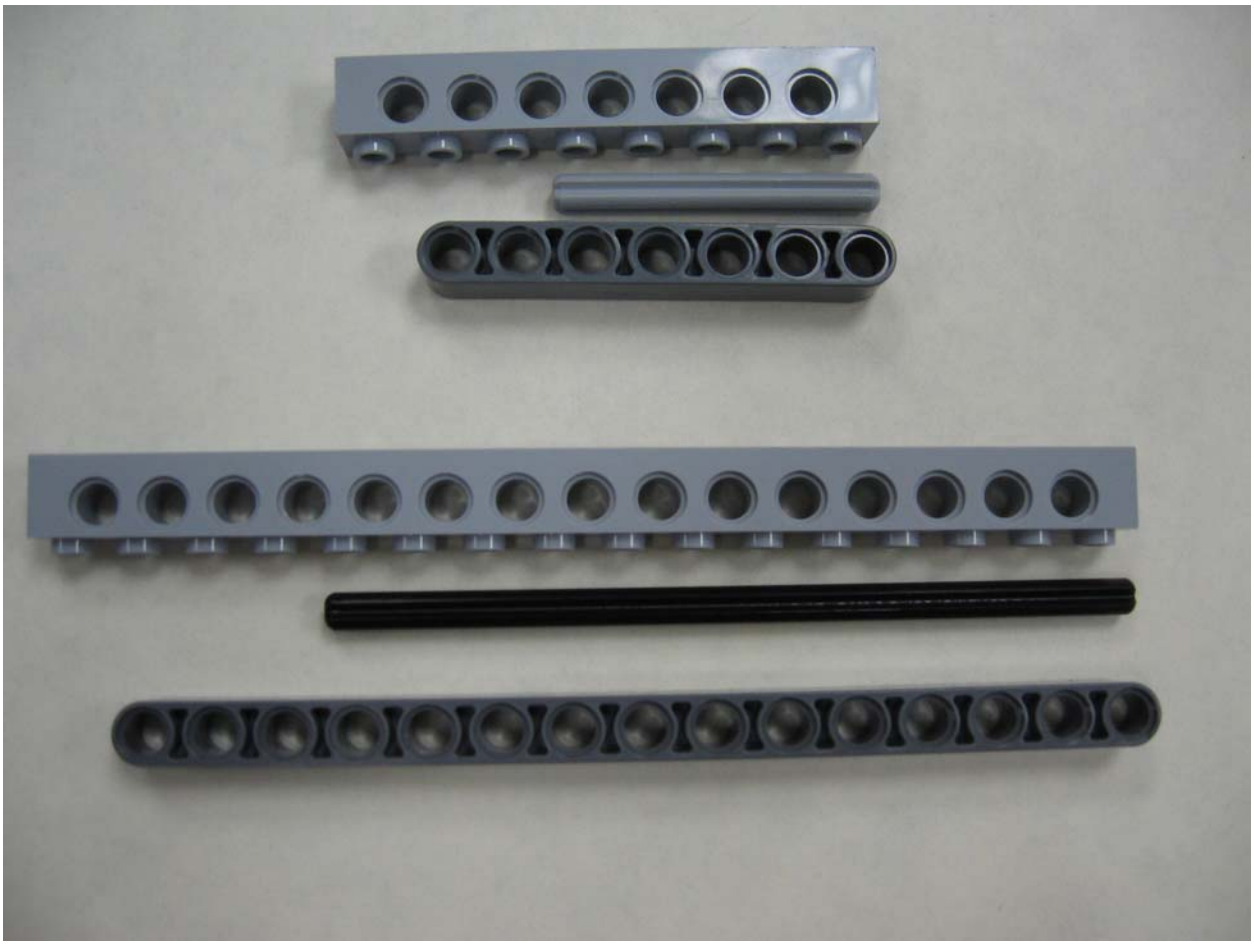


Figure 8. Measuring the lengths of cross-axles.

Figure 9 shows two types of bushings that are included with the NXT kit, a small yellow busing and a longer gray bushing. Each of these components has a crossed-shaped internal hole that mates with any of the cross-axles. Bushings are used to limit the travel of a cross-axle along its axis. They are also used as spacers. The small yellow bushing has a groove along its circumference, allowing it to be used as a pulley as well.

Figure 10 shows a variety of connectors that are supplied with the NXT kit and the resource kit. These components provide different secure connections between combinations of beams and cross-axles, in the TECHNIC® building style. Figure 11 shows samples of the types of gears that are included in the NXT kit and the resource kit. In addition to standard spur gears, the kits supply racks (upper right), bevel gears (lower right), worm gears (screw-like component at left), and crown gears (top, second from left). All of these gears except the racks have center cross-holes to accept cross-axles and cross-pegs. The resource kit also includes a differential housing (lower center).

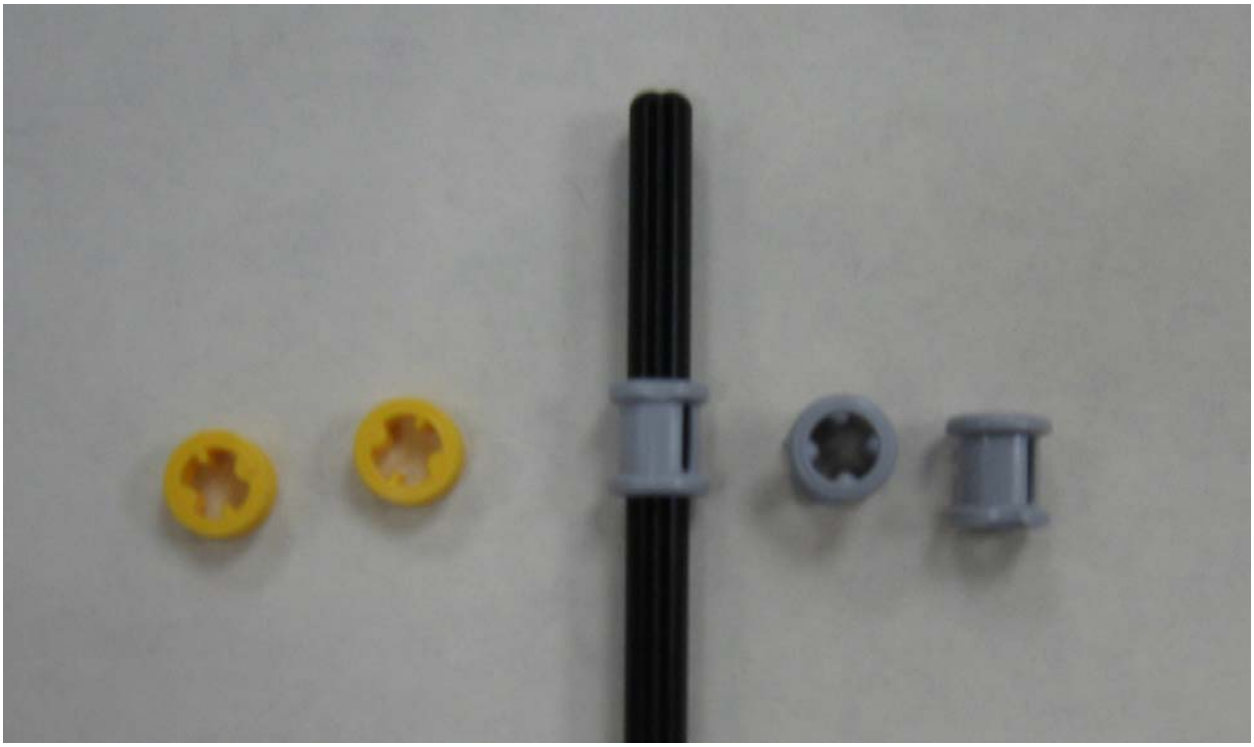


Figure 9. Bushings included in the NXT kit.

Figure 10. TECHNIC® connectors.

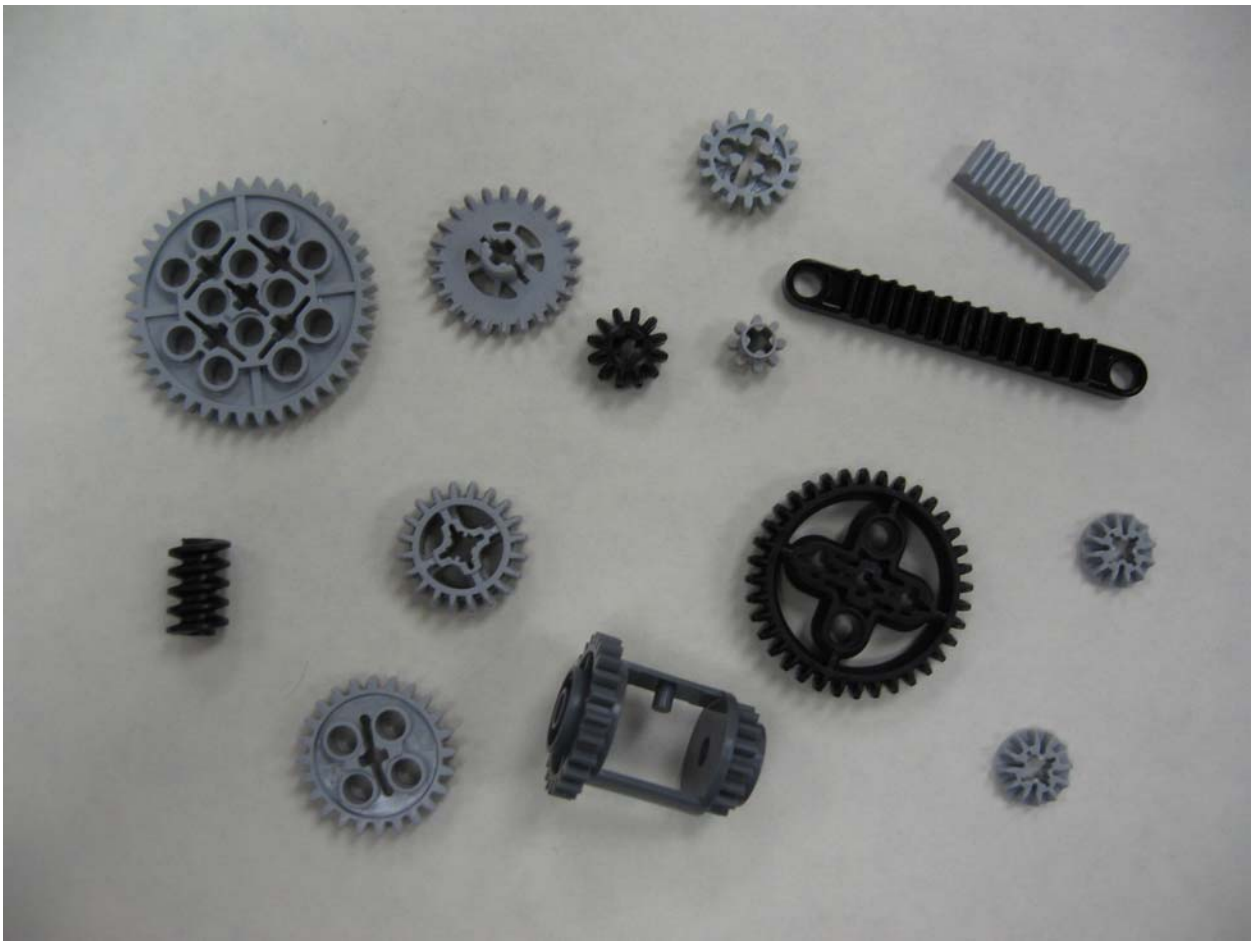


Figure 11. LEGO® gears.

Building Stable Structures

You can readily build stable structures with TECHNIC® components by following a few simple rules. The web site at http://technic.lego.com/technicdesignschool/courses.asp contains links to several tutorials with tips for increasing the stability of your LEGO® creations.