ACTIVITIES CREATED IN COLLABORATION WITH NASA SCIENTISTS AND ENGINEERS.

HERE'S TO A UNIVERSE OF ASTRONAUTS, SCIENTISTS, THINKERS AND TRAILBLAZERS.

love, littleBits
WARNING

• This product contains small magnets. Swallowed magnets can stick together across intestines causing serious infections and death. Seek immediate medical attention if magnets are swallowed or inhaled.
• Most modules are small parts. DO NOT allow children under 3 years old to play with or near this product.
• NEVER connect any modules or circuits to any AC electrical outlet.
• Do not touch or hold any moving parts of modules while they are operating.
• Keep conductive materials (such as aluminum foil, staples, paper clips, etc.) away from the circuit and the connector terminals.
• Always turn off circuits when not in use or when left unattended.
• Never use modules in or near any liquid.
• Never use in any extreme environments such as extreme hot or cold, high humidity, dust or sand.
• Modules are subject to damage by static electricity. Handle with care.
• Some modules may become warm to the touch when used in certain circuit designs. This is normal. Rearrange modules or discontinue using if they become excessively hot.
• Discontinue use of any modules that malfunction, become damaged or broken.

VERY IMPORTANT NOTE

• Several projects in this kit involve the use of a box cutter and/or a hot glue gun. These tools should be used ONLY under direct adult supervision and ONLY by children capable of using them safely.

INSTRUCTIONS

NEVER connect any modules or circuits to any AC electrical outlet.

CARE AND CLEANING

Clean modules ONLY by wiping with a dry cloth. If necessary, isopropyl alcohol on a cloth may be used sparingly. DO NOT use any other cleaning products on modules.

GOOD QUESTION?

Visit littlebits.cc/faq for troubleshooting and additional support.

www.littlebits.cc

littleBits Electronics, Inc.
60 E. 11th Street, Fifth Floor
NY, NY 10003
(917) 464-4577

You are a proud owner of the Space Kit v1.

Over 1,000,000 combinations?! Are you serious?

Yep, www.littlebits.cc/mathmagic

Released under CERN Open Hardware License, Version 1.2

Design By: littleBits Electronics, Inc.

Information in this activity booklet was created in collaboration with the NASA Goddard Space Flight Center and the AURA program. littleBits Electronics, Inc. 2014

Made in Dongguan City, China

littleBits, Bits, Circuits in Seconds, and Make Something That Does Something are trademarks of littleBits Electronics, Inc.
1 CIRCUITS IN SECONDS
littleBits makes an expanding library of modular electronics that snap together with magnets.

2 COLOR CODED
Modules are grouped into four different categories, which are color coded:
- **POWER** is needed in every circuit and the start of all your creations.
- **INPUT** modules accept input from you and the environment and send signals to the modules that follow.
- **OUTPUT** modules DO something—light, buzz, move...
- **WIRE** modules expand your reach and change direction—great for helping to incorporate modules into your projects.

3 ORDER IS IMPORTANT
- **Power Modules** always come first and **Input Modules** only affect the **Output Modules** that come after them.

4 MAGNET MAGIC
littleBits modules snap together with magnets. The magnets are always right; you can’t put modules together the wrong way.

5 littleBits + anything
The modules are just the beginning. Combine them with craft materials, building sets, and other toys to electrify your life. We’ll show you how!

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You always need a blue and a green; pink and orange are optional, in between.

NEED HELP?
For troubleshooting and additional support, visit littleBits.cc/faq
This power module lets you use a 9-volt battery to supply electricity to your other modules. Snap in the battery & cable (both included) and flip the switch to turn it on.

The remote trigger lets you use a common remote control with your modules. Make your littleBits circuit and point your remote control at the remote trigger’s sensor. Then, press any button on your remote control to activate the module. It will work with almost any button on a remote that uses infrared light to send signals.
The light sensor measures how much light is shining on it. It has two modes: “light” and “dark.” In “light” mode, the more light the sensor receives, the higher the signal it sends out. In “dark” mode, it’s just the opposite – the signal increases as light decreases.

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The microphone module translates sound into the electronic language of littleBits. You can use it to turn sounds into light or motion, or use it with the speaker module like a small megaphone! Make sure the switch is set to “sound” when you’re using it with the speaker, and “other” for all your other modules.

The wire is just what it sounds like – it allows you to physically separate your modules, turn corners and build your circuit in any direction. Try it whenever you need to break up your chain, like when you need to put a sensor on the top of your rover! You’ll find many situations where you’ll want a wire.
The IR LED (or infrared light-emitting diode) module sends out light with longer wavelengths than visible light, similar to the light in your remote control. It's invisible to the eye, but many digital cameras can see it! Try using it to activate the light sensor or remote trigger.

The number module gives you a look into how your modules work: it displays information about the signal it’s receiving from your other modules. It has two modes: in “value” mode, it displays a number from 0 to 99 based on the input. In “volts” mode, it displays the actual voltage it is receiving, from 0.0 to 5.0 volts.

The speaker amplifies sound from modules like the microphone or other sources like mp3 players. It also features a headphone output for personal listening. The speaker is connected with 3M™ Dual Lock™ so it can be removed from its circuit board. To reattach, hold module and press together firmly.
The DC (or “direct current”) motor rotates a shaft when you send it an on signal. It has a switch to set the direction of rotation. Try attaching various things to make robotic space arms, orbiting satellites, and rovers.

**DC MOTOR o5**

The DC (or “direct current”) motor rotates a shaft when you send it an on signal. It has a switch to set the direction of rotation. Try attaching various things to make robotic space arms, orbiting satellites, and rovers.

**BRIGHT LED o14**

The bright LED is a small module that puts out a big light. Just like our other LED modules, it’s a great way to shed some light on your creations. Choose the bright LED when you want a lot of bright white light.

**MOTORMATE™ a10**

The motorMate works with the DC motor. This makes it easy to attach wheels, paper, cardboard, and lots of other materials to the motor. Simply slide it on the “D” shape on the shaft. A LEGO® axle also fits in the end.

**SCREWDRIVER a4**

This little purple screwdriver is used to modify any module with a micro adjuster.

**AUDIO CABLE a16**

This cable is for connecting your microphone or speaker module to an audio source, like an mp3 player or smartphone.

**LED - “light-emitting diode”**

**place this end on the DC motor shaft**

**change direction**

**This cable is for connecting your microphone or speaker module to an audio source, like an mp3 player or smartphone.**

**This little purple screwdriver is used to modify any module with a micro adjuster.**
TRY THESE CIRCUITS

Get started with these, but don’t let us hold you back – every module fits with every other module – feel free to experiment.
What is Energy?

Energy comes in many forms and can transform from one type of energy to another.

1. Potential Energy: The battery is an example of potential (or stored) energy.
2. Electrical Energy: When your power is turned on, the battery is transferring the stored energy to electrical energy.
3. Kinetic Energy: The DC motor is an example of kinetic (moving) energy because it spins.
4. Sound Energy: The energy is transferred to sound energy by the speaker.
5. Electromagnetic Energy: Light emitted by the bright LED is an example of electromagnetic energy.

Sound waves are both potential and kinetic energy. When the speaker moves, it compresses air molecules nearby, giving that air potential energy. When the air expands, potential energy is transformed into kinetic energy. Waves created by compressing and expanding matter – such as air molecules – are called compression waves.

Wavelength: The distance from crest to crest or trough to trough of a wave.

Sound doesn’t stop when you plug in audio cables and music source.

Electrical Energy: The DC motor is an example of kinetic energy because it spins.

An electromagnetic wave can also be described in terms of its energy – in units of measure called electron volts (eV). Moving along the spectrum from long to short wavelengths, energy increases as the wavelength shortens. Consider a jump rope with its ends being pulled up and down. More energy is needed to make the rope have more waves.

Potential Energy: The battery is an example of potential (or stored) energy.

Kinetic Energy: The DC motor is an example of kinetic (moving) energy because it spins.

Electromagnetic Energy: Light emitted by the bright LED is an example of electromagnetic energy.

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**ELECTROMAGNETIC ENERGY**

When you tune your radio, watch TV, send a text message, or pop popcorn in a microwave oven, you are using electromagnetic energy. Without it, the world you know could not exist.

**ELECTROMAGNETIC WAVE**
Electricity can be static, like the energy that can make your hair stand on end. Magnetism can also be static, as it is in a refrigerator magnet. A changing magnetic field will create a changing electric field and vice-versa, the two are linked. These changing fields form electromagnetic waves.

**ELECTROMAGNETIC SPECTRUM**
Electromagnetic energy travels in waves and spans a broad spectrum from very long radio waves to very short gamma rays. The human eye can only detect a small portion of this spectrum called visible light.

Light is also energy that travels in waves. You cannot see these waves like you can see ocean waves, but you can see their energy as visible light.

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**SCIENCE IN ACTION**
Say the Energy Meter Project p.14
Enhanced instructions plus tons more projects online, littleBits.cc/space

DOWNLOAD ACTIVITIES ONLINE AT WWW.LITTLEBITS.CC/SPACE
PROJECT 1: An introduction to speakers and mechanical waves.

WAVE GENERATOR

1. Start with this circuit.
2. Play song on mp3 player and gently touch speaker cone.
3. Attach spoon to speaker with tape.
4. Pour milk into spoon, then play some songs.
5. Turn up your volume and check out the cool wave patterns!

You’ll need:
- pen
- spoon
- tape
- milk
- mp3 player
- audio cable

Describe how different music causes different reactions in the liquid.

Having trouble? Try different songs until you see some waves.

Why’d it do that?
Refer back to What is Energy on p.10
Digital cameras create images by measuring light energy. This is similar to how NASA satellite images are created by measuring energy reflecting off the Earth’s surface.

**PROJECT 2: Discover sources of light energy around you.**

**ENERGY METER**

1. Start with this circuit.

2. Walk around and find different sources of energy. Record your findings in table.

3. Move the sensor closer or farther from the energy source. Record your observations in table.

4. Can you see any energy coming from a TV remote control? What happens if you point it at the energy meter and press a button?

   - 1.
   - 2.
   - 3.
   - 4.

   **Describe what happens when you move the sensor closer to or farther from the energy source.**

   ____________________________

   **What happens if you point a household remote at the light sensor?**

   ____________________________

   **WHY'D IT DO THAT?**

   Refer back to Electromagnetic Energy on p.11

   FOR EXPANDED ACTIVITY, GO TO littleBits.cc/energymeter

   **TIME:** 15 mins

   **DIFFICULTY:** ★★★★★

   **YOU’LL NEED**

   - pen

   For expanded activity, go to littleBits.cc/energymeter

Digital cameras create images by measuring light energy. This is similar to how NASA satellite images are created by measuring energy reflecting off the Earth’s surface.

NASA images by Reto Stöckli, based on data from NASA and NOAA.
**PROJECT 3: Explore light waves you can see.**

**MAKE A SPECTRUM**

1. **Make this circuit.**

   ![Circuit diagram]

   **power**

   ![Wire]

   **bright LED**

2. **Find a dark place and set the reflective side of the CD opposite a white wall or piece of paper.**

3. **Place a bright LED in between the CD and the wall (or paper).**

**TIME: 15 mins**

**DIFFICULTY:** 💫💫💫💫💫

**YOU’LL NEED**

- white paper
- CD

**MAKE A SPECTRUM!**

How many colors can you find?

**A SPECTRUM** is a range of electromagnetic waves in order of their wavelength. You can always remember the order by thinking of “ROY G BIV.” From longest to shortest – Red, Orange, Yellow, Green, Blue, Indigo, Violet.

- Red
- Orange
- Yellow
- Green
- Blue
- Indigo
- Violet

As white light bends, each color in the spectrum bends at a slightly different angle because their wavelengths are different sizes. Shorter wavelengths will bend more and longer wavelengths will bend less.

Why does a CD behave like a prism? They both act as “diffraction grating.” The grooves on a CD diffract light into several beams like you saw in this experiment!

- Refer back to Electromagnetic Energy on p.11

**WHY'D IT DO THAT?**

- Reflector side of the CD opposite a wall or piece of paper.

- Bright LED in between the CD and the wall (or paper).

- White light bends as it passes through the CD, creating a spectrum of colors.

- Each color bends at a slightly different angle due to their different wavelengths.

- Shorter wavelengths bend more, while longer wavelengths bend less.

- This effect is similar to how a prism works, acting as a “diffraction grating.”

- The grooves on a CD create multiple beams of light, similar to how a prism diffracts light.
PROJECT 4: Learn how satellites detect particles in the atmosphere.

MEASURING THE ATMOSPHERE

1 Make these two circuits.

- Power wire
- Light sensor wire
- Number

![Circuit Diagram]

You’ll need:
- Pen
- Glass and water
- Milk
- Drinking straw
- Plastic wrap

**TIME: 30 mins  
DIFFICULTY: ⭐️⭐️⭐️⭐️

The numbers you observe are the "data" you are gathering.

This project is similar to how satellite instruments measure the atmosphere. Since aerosols and gases scatter light differently, NASA instruments can determine the composition of the atmosphere by measuring how light is scattered.
4. Measure the amount of energy coming through the side of the glass. Record your data in table.

5. What do you think will happen to the number if you add a drop of milk to the water? Record your hypothesis. Now conduct an experiment to find out if you were right.

Scientists use what they know to make a guess about what may happen. This is called a “hypothesis.”

6. Add 1 drop of milk and stir. The milk represents particles in the atmosphere.

7. Continue adding milk and record your observations. Repeat steps 3 and 4 and record your data.

Hypothesis: ____________________________

<table>
<thead>
<tr>
<th>Water</th>
<th>Bottom</th>
<th>Side</th>
</tr>
</thead>
<tbody>
<tr>
<td>1 drop</td>
<td></td>
<td></td>
</tr>
<tr>
<td>2 drops</td>
<td></td>
<td></td>
</tr>
<tr>
<td>3 drops</td>
<td></td>
<td></td>
</tr>
<tr>
<td>4 drops</td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

Was your hypothesis correct?

Measuring from bottom: With water, the reading will be high because light is traveling downward. With milk, the reading will be lower because light is scattered.

Measuring from side: With water, the reading will be low because light is traveling downward. With milk, the reading will be higher because the light is scattered.

Why not try some other liquids as well? Orange juice, soda, etc.

Measuring from bottom: With water, the reading will be high because light is traveling downward. With milk, the reading will be lower because light is scattered.

Measuring from side: With water, the reading will be low because light is traveling downward. With milk, the reading will be higher because the light is scattered.
PROJECT 5: Learn how to wirelessly transmit music using a digital signal.

**DATA COMMUNICATION**

1. Make these two circuits.
   - **Power**
   - **Mic**
   - **IR LED**
   - **Bright LED**
   - **Speaker**
   - **Light Sensor**

2. Plug audio cable into microphone module and an mp3 player and play your favorite song.

3. Place both circuits on a flat surface, like below.
   - **Transmitter**
   - **Receiver**
   - Hold at least 12” away from light sensor.
   - Make sure the IR LED is at a 90° angle to the light sensor and adjust sensor to minimum sensitivity.

4. Now swap out the IR LED for the bright LED and see what happens.
   - **IR LED**
   - **Bright LED**
   - Use screwdriver to adjust sensor to minimum sensitivity.
   - Hold about 3” above light sensor.

5. Put different materials between the light source and sensor. What happens?
   - **Try blocking the light sensor with your hand or a piece of paper!**

**How does it work?**
Your digitized music is converted into a series of light wave pulses. The pulses are decoded by the light sensor and converted into sound waves by the speaker.

**NASA uses electromagnetic waves to communicate with satellites orbiting Earth.**

**TIME: 30 mins**

**DIFFICULTY:** ★★★★★

NASA TODAY
PROJECT 6: Learn the science behind satellites and make your own parabolic reflector.

**SATELLITE DISH**

1. **Make these two circuits.**

   - **power**
   - **wire**
   - **light sensor**
   - **wire**
   - **number**

   ![Circuit Diagram]

   **TIME:** 60 mins  
   **DIFFICULTY:**  
   **YOU’LL NEED:**  
   - hot glue  
   - tape  
   - scissors  
   - paper bowl  
   - plastic cup  
   - craft stick  
   - foam ball  
   - foil  
   - rubber band

   **STAY SAFE!** Always use with an adult.

2. **Find a paper or plastic bowl and cover it with foil.**

   - **hot glue**
   - **foil to bowl**

   **To optimize the amount of light that is reflected into your sensor, you’ll need to calculate where the focus point is.**

3. **Try to find a shallow bowl, it will work best then off any excess foil.**

   - **parabolic curve**
   - **like your bowl**

   Use **craft stick** to make a sensor arm.

   **The dimensions will depend on the shape of your bowl.**

4. **Try to align tip of stick in middle of bowl.**

   - **hot glue like this**

   Once you have found the ideal focus point, glue craft stick to bowl.

5. **To learn how to calculate the focus distance, go here:**

   - **littleBits.cc/satellitedish**

   **To learn how to calculate the focus distance, go here:**
6. Rubberband light sensor to tip of arm. It should face into bowl.

7. Create a mounting stick.

8. Cut slit in bottom of cup.

9. Stick satellite dish into cup through the slit.

10. Use tape and place number module on front of cup.

11. Shine bright LED into your dish... what happens to the number reading?

Decorate by adding foam ball at tip of stick on other side of light sensor.

Cut foam ball in half.

Adjust sensitivity of the light sensor with screwdriver.

Try different shapes like a mixing bowl or pot lid and see if you can improve your design!
THE DEEP SPACE NETWORK (DSN) is a worldwide network of antennas developed by NASA to communicate with robotic spacecraft exploring our solar system and beyond. Sensors on board this spacecraft gather and transmit data about distant planets, moons, asteroids, comets, stars, and galaxies.

Receiving data from this spacecraft is very challenging because of the extreme distances between the spacecraft and Earth. Signals must travel millions or even billions of kilometers between Earth and a spacecraft in deep space. The spacecraft’s communications equipment — designed to be small and lightweight — transmits at very low power, typically about the same as a refrigerator light bulb. Receiving antennas on Earth must have large collectors (antenna dishes) with precisely shaped surfaces and they must accurately point towards the spacecraft.

The DSN has three ground stations located approximately 120 degrees apart on Earth (120 + 120 + 120 = 360). This is to ensure that as the Earth rotates, at least one station is able to capture and transmit signals to any deep space mission without any gaps in coverage.
PROJECT 7: Learn about astronomy and project the night sky in your room.

STAR CHART

1. Start with this circuit.

2. Cut the bottom off of a plastic cup.

3. Trace wide end of the cup on a piece of cardboard and cut it out.

4. Tape bright LED on top of cardboard circle.

TIME: 60 min
DIFFICULTY: ★★★★☆

YOU’LL NEED:
- box cutter
- scissors
- pen
- tape
- cardboard
- plastic cup
- colored paper

For expanded activity, go to littleBits.cc/starchart
1. Roll a piece of paper into a cone and place cup inside.
2. Tape light sensor on the outside of the cone.
3. Print out a star chart. You can download one at littleBits.cc/starchart.
4. Create a handle out of cardboard.
5. Turn off the lights, the darker it gets the brighter the stars will be!

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**PROJECT YOUR STAR CHART**

1. Roll a piece of paper into a cone and place cup inside.
2. Tape light sensor on the outside of the cone.
3. Print out a star chart. You can download one at littleBits.cc/starchart.
4. Create a handle out of cardboard.
5. Turn off the lights, the darker it gets the brighter the stars will be!
NASA instruments measure energy in the night sky across the electromagnetic spectrum. By looking at the sky in wavelengths beyond the visible spectrum, scientists can see a more complete picture. This helps them study questions like ‘how was the universe formed’ and ‘how is it changing.’

Orion is one of the most widely recognized of all the 89 constellations in the sky. It is also one of the oldest known to humans. The Ancient Egyptians called it Osiris as long ago as 2000 BC!

The brilliant stars that make up this rectangular star pattern seem to be close-by because they are so bright, but in fact they are very far away. Astronomers measure distances using a unit called the light year, which equals about 5.9 trillion miles (9.5 trillion km), or 63,240 times the distance from Earth to the Sun!

TRY THESE CALCULATIONS!
The bright star in Orion called Betelgeuse is located 650 light years from Earth. What is this distance in miles or kilometers?

Betelgeuse is expected to blow up as a supernova sometime in the next million years. Suppose this happened in the year 3000 AD. In what year would someone on Earth see this explosion? Go online to find the answers, littleBits.cc/starchart
PROJECT 8: Learn about how satellites take photos of the Earth.

SATELLITE ORBIT

1. Make this circuit.

2. Make a ring. Trace a large plate and then a small plate on a piece of cardboard and cut them out.

3. Cut a slot in a plastic cup.

4. Fill the cup with some weight.

5. Cover cup with circular piece of cardboard and tape it down.

TIME: 90 min
DIFFICULTY: ★★★★★

You’ll Need:
- hot glue
- box cutter
- clip sharpeners
- plastic cup
- cardboard (large)
- weight
- plates
- tape
- pipe cutter
- remote

STAY SAFE! Always use with an adult.

We used nuts and bolts, use what you have at home!
6 Stick skewer through the cardboard curve and the center of the foam ball.

7 Place the cardboard curve in the slot in the cup and tape in place.

8 Make a cardboard shelf for the DC motor.

9 Then glue to center of cardboard curve.

10 Attach pipe cleaner to motorMate and put on the DC motor.

11 Tape the DC motor to the cardboard shelf.

12 Add satellite to end of pipe cleaner.

13 Decorate your model.

The Earth is on a 23° tilt.

Stick skewer through the cardboard curve and the center of the foam ball.

Cut slot same width as cardboard.

Slide enough to fit DC motor.

The skewer should be tilted like the Earth’s axis.

The Earth is on a 23° tilt.

Hot! Be careful!

For expanded activity, go to littleBits.cc/orbit
Every day, NASA satellites (like AURA pictured to the left) collect global observations of the Earth. The image to the right shows the path of the Aqua satellite. Data is only collected when the satellite is on the sunlit side of the Earth because it measures reflected light from the Sun. With each orbit, the MODIS sensor onboard the satellite can observe a swath of data over 1400 miles (2253 km) wide and can image almost the entire Earth surface everyday.

A satellite at an altitude of 438 miles (705 km) orbits Earth once every 99 minutes. How many orbits does the satellite make in a day? How many times does it cross the equator in one day?

Press button on remote

Images Courtesy NASA
PROJECT 9: Learn NASA engineering by building this robotic space arm.

GRAPPLER

A GRAPPLER is on the end of the ISS Robot Arm and is used to grab onto objects in space – like astronauts!

TÔ S IS A 3RD PROJECT, TRY IT WITH A PART!

STAY SAFE! Always use with an adult.

TIME: 90 mins
DIFFICULTY: 🌟🌟🌟🌟

START WITH THIS CIRCUIT:

1. Cut the bottom off of 2 plastic cups. Smart! Be careful!
2. Cut three pieces of string the same length. Tape them to the inside of one cup.
3. Place the other cup over the cup with strings. Feed the strings up through the top of both cups. Tape them to the outside of the outer cup.

YOU'LL NEED:
- Box cutter
- Glue gun
- Grill cutters
- Scissors
- Drawing tool
- Rubber band
- Tape
- Plastic cups
- String
- Cardboard
- Craft stick
- Ruler
- Remote

The strings should be a little longer than the diameter of the plastic cup.

Wow! Twist the two cups to see what happens.

Image Courtesy NASA

STAY SAFE! Always use with an adult.
Use a household remote to control your grappler. This is similar to the arm that grabs onto moving vehicles in space!

What are other ways to prevent the outer cup from spinning?

5. Trace wide end of cup on cardboard and cut out circle.

6. Cut the end off a craft stick and stick into motorMate.

7. Tape cardboard circle to inner cup and stick the craft stick in the hole.

8. Put the circuit on a ruler and use rubberbands to hold in place.

9. Place motorMate onto D-shaft of the motor.

10. Secure the outer cup to the ruler using wooden skewers and tape. Make sure lip of the outer cup is half an inch higher than the inner cup.

Put a dab of hot glue here to secure craft stick.

Tape cardboard circle to inner cup and stick the craft stick in the hole.

Cut the end off a craft stick and stick into motorMate.

Cut a small hole.

Place motorMate onto D-shaft of the motor.

Secure the outer cup to the ruler using wooden skewers and tape.

Tape cardboard circle to inner cup and stick the craft stick in the hole.

What are other ways to prevent the outer cup from spinning?

Flip the mode switch on the DC motor to release.
**PROJECT 10: Learn how NASA scientists are able to explore new worlds!**

**MARS ROVER**

1. Make this circuit.
   - power
   - remote trigger
   - wire
   - DC motor
   - wire
   - light sensor
   - number
   - motorMate

   **STAY SAFE!** Always use with an adult.

   **You'll NEED**
   - hot glue
   - box cutter
   - tape
   - scissors
   - plastic cups
   - cardboard
   - craft sticks
   - paper tube
   - cardboard boxes
   - ruler
   - drinking straw
   - remote

   **TIME:** 2 hrs
   **DIFFICULTY:** ★★★★★

2. Make the big wheel.
   - Cut the tops off of two plastic cups
   - Slide them together, then facing out

3. Make 2 cardboard circles for the inside of the big wheel.
   - Circles need to be the same diameter as the inside of the big wheel
   - Make a cut the size of a craft stick at the center of the circles

January 2004
Mars Exploration Rover “Opportunity” lands.

Image Courtesy NASA/JPL-Caltech
Attach the wheel. Make 6 wheels!

Cut six cardboard circles to fit inside the wheels.

Place cardboard circle in paper tube and glue in place.

Make an axle holder for the craft stick on your wheel.

Cut a hole in the base of a box large enough to fit your wheel.

Put the craft stick through the slots and add the motorMate to one end of it.

Make a strip of cardboard and make a hole in one side.

Attach the wheel. motorMate connects to the D-shaft of the DC motor.

Put the craft stick through the slots and add the motorMate to one end of it.

Make 6 wheels!

Cut six cardboard circles to fit inside the wheels.

Place cardboard circles on both sides of the wheel and glue in place.

Cut a strip of cardboard and make a hole in one side.

Place DC motor directly across and tape down well.

Make sure that the craft stick is long enough so that it stays in place when the wheel spins.

Put the craft stick through the slots and add the motorMate to one end of it.

Start by cutting paper tubes.

We'll show you one way to make them, but use what you have to create your own!

Use a sharpie to poke hole in center.
In May 2013, the Mars Exploration Rover “Opportunity” exceeded 22.22 miles (35.76 km) since its landing in January 2004. This breaks the record for the greatest distance driven by a NASA vehicle on a world other than Earth since the Lunar Roving Vehicle was driven 22.21 miles (35.74 km) on the moon, in December 1972.

...Mars Rover Continued

12 Make holes for axles.

13 Put the wheels on.

14 Arrange everything in the box.

15 Put a craft stick vertically through your cardboard shelf near the front.

16 Stick a small box on top of the craft stick and hot glue in place.

PRO TIP: you may need to build a cardboard shelf for your modules to sit on

Tape everything down making sure that nothing interferes with the axles.

Pick a small, lightweight toy, like a juice box, for a craft stick.

Stick a small box on top of the craft stick and hot glue in place.

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NASA engineers send instructions to the rovers via radio communications. Depending on where the planets are in their orbits, a radio signal traveling at the speed of light will arrive on Mars between just over 3 minutes or as long as 20 minutes. Due to these time delays it is impossible to communicate with and control the rover in real time. To send instructions to rovers on Mars, NASA scientists must have a line-of-sight between Earth and Mars. Occasionally Earth and Mars are on opposite sides of the sun, called conjunction. During this time, the sun can disrupt or block radio communication between the two planets.

Image Courtesy NASA/JPL-Caltech
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