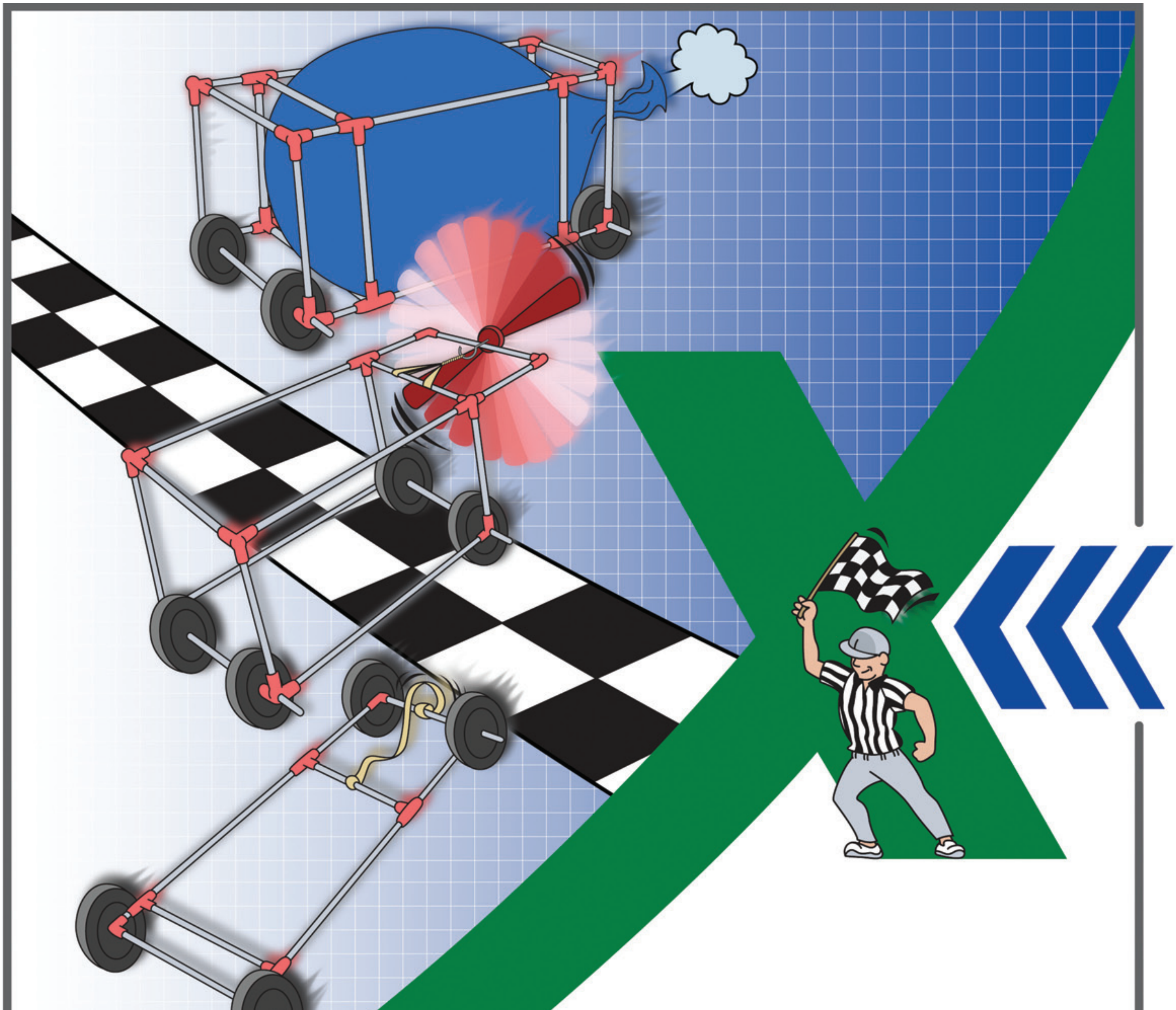

Transportation:
Quest for Speed

Pratt School of Engineering, Duke University
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Discover Engineering

Student Handouts

Activity 1: Spooling Around

Name: ______________________ **Date:** ____________

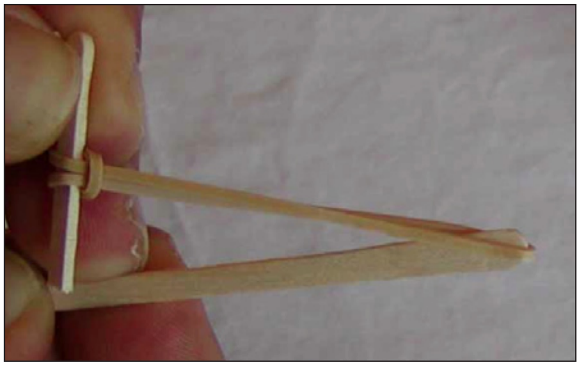
Assembling your spool car:

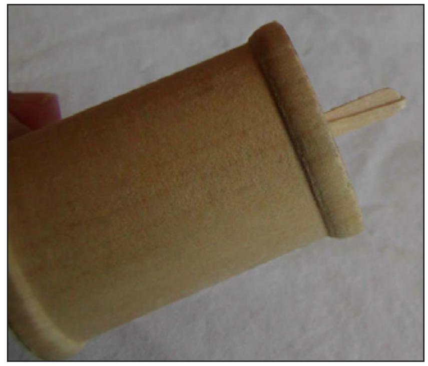
1) To begin building the spool car, snap a craft stick into two pieces so that one of them is slightly shorter than the diameter of the spool, as shown below.

2) Attach a size #16 rubber band to the craft stick, as shown below. Wrap the rubber band around the stick and pass the free end back through the loop.

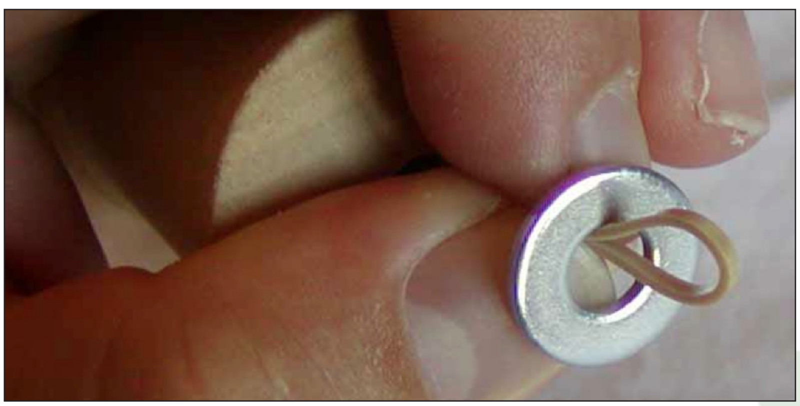
Activity 1: Spooling Around

3) Pass the free end of the rubber band through the hole in the center of the spool. To do this, stretch the end around a craft stick, as shown below, then poke it through the center hole to the other side, where you can grab it with your fingers. You must continue to hold on to the rubber band after it is through the spool for the remaining steps.

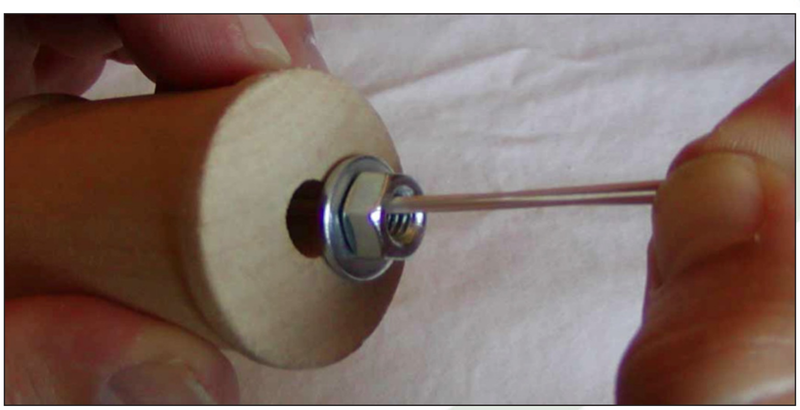




4) While continuing to hold the rubber band with your fingers, pass the end through the hole in the center of the flat washer, as shown below.



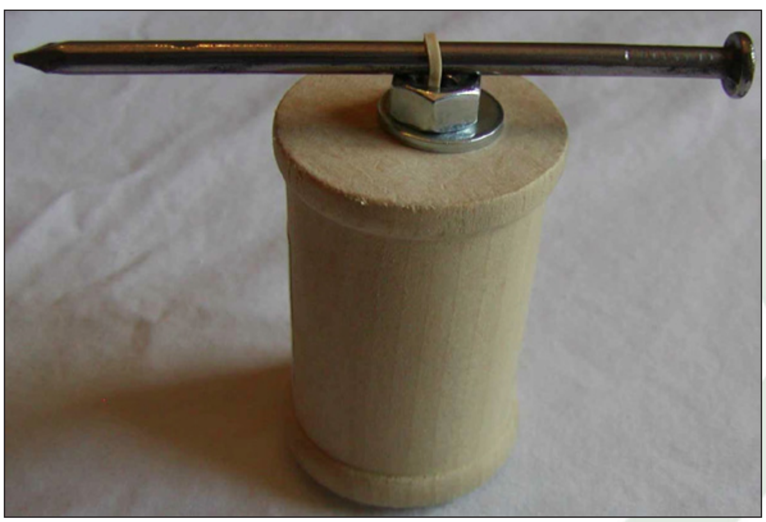
5) Pass the band through the center of the nut, as shown below.



Activity 1: Spooling Around

6) Pass the nail through the loop of the rubber band and let go of it. It should look like the picture below.
7) Choose a flat surface for testing your spool car, such as the floor or a tabletop. Designate a starting line with a piece of tape.
8) Before testing your car, predict what you think will happen to the distance and efficiency as you increase the number of nail turns. Write your answer in the box.

9) You are now ready to test your spool car. Hold the spool in one hand and wind the nail several times, holding the head between your thumb and forefinger and turning it clockwise as you would a dial. Once you're done, set the spool at the starting line and let it go. The first time the spool is wound, you will need to turn the nail several turns to wind the rubber band enough to move the car. The rubber band will not completely unwind when it stops moving, so the next time you start the car, fewer turns of the nail will be necessary.
10) Now experiment with modifying your design to try to improve the car's performance. Then test the car again and measure the results. Record your results in the table.



Completed Spool Car

Activity 1: Spooling Around

Activity 1: Spool Car - Test Results Table

Test #	Nail Turns (turns)	Distance (inches)	Car Efficiency (inches/turn)	Notes
Example:	10	5	10 ÷ 5 = 2	Changed design to improve...
1				
2				
3				
4				
5				
6				
7				
8				
9				
10				
11				
12				
13				
14				
15				
16				
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20				

Activity 2: Ramp-Powered Car

Name: ______________________________ **Date:** ______________

Engineering Design Challenge

When engineers create a new design, one of their first tasks is to understand the restrictions that are imposed by the nature of the product and its purpose. For example, an automobile they design must be narrow enough to fit in one lane on the road and it may be required to run on 87-octane gasoline. These specifications and restrictions are referred to as "design constraints."

For today's design challenge, you are to develop a car using the materials in the K'NEX® Motion and Design Set provided by your instructor. The cars will have no on-board power source. You will operate them by letting them roll down an inclined surface.

Your design objective is to achieve the fastest speed over the distance specified by your instructor.

Optimize your design for fastest possible speed within the following design constraints:

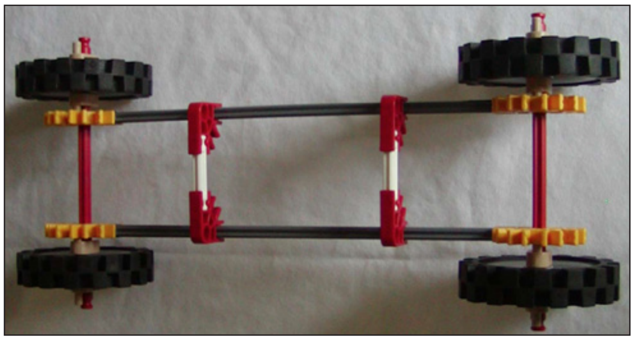
1. Wheelbase must be between 3.5" and 17.0" (distance between the front and rear axles).
2. Length must be between 4.5" and 21.0".
3. Width must between 2.25" and 5.5".
4. Maximum height is 8.0".

Record your test results in the table. Keep notes about the various test-runs, such as what type of ramp was used, how rough the surface was, anything you may have changed in the car's design and whether the modifications improved performance.

Activity 2: Ramp-Powered Car

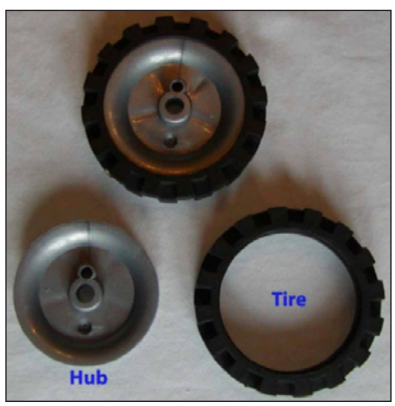
Ramp-Powered Car Prototype Instructions (optional)

1) A completed ramp-powered car is pictured below. It is not necessarily the best design possible, but it will work fairly well. Feel free to use your own design or make improvements to this one.

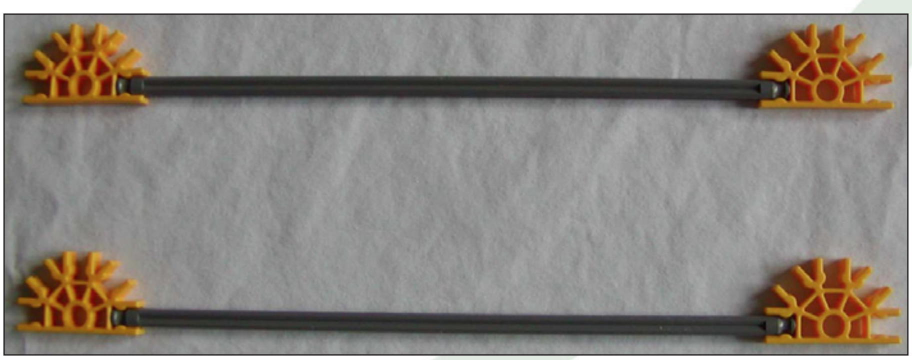


Prototype of Ramp-Powered Car

2) To build the car shown, start by placing the black rubber tires onto the silver plastic hubs. You will need to use a bit of force to get the tire to wrap around the hub. The K'NEX® Motion and Design set contains two kinds of hubs and tires, narrow and wide. All the following photos show wide wheels.

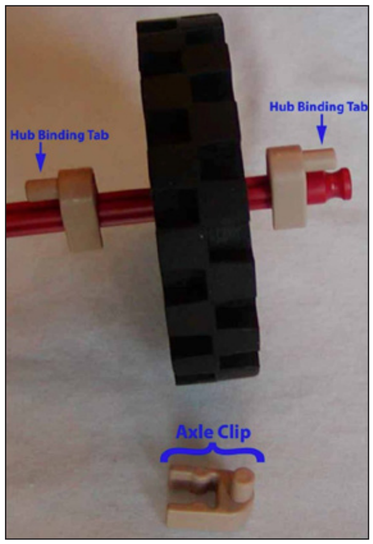


3) Take two long, gray rods and four yellow connectors and snap them together, as shown below, to form the side-frame rails of the car.



Activity 2: Ramp-Powered Car

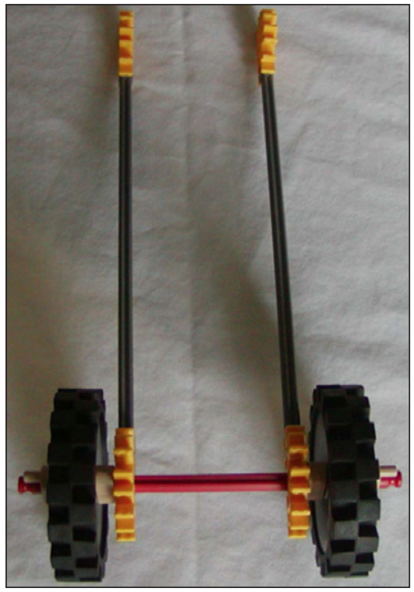
4) Now take a red rod and pass it through the center hole in the hub of one of the wheels. The two red rods will be the "axles" of the car. Snap two tan-colored axle clips onto the red axle rod, one on each side of the wheel. Make sure that the hub binding-tabs on the axle clips are pointing away from the silver wheel hub, as shown below. After you snap the clips onto the axle, slide the two clips and wheel to one end of the axle.



5) Pass the long end of the red axle through the center holes at the ends of both yellow connectors. Now attach the second wheel and axle clips to the other end of the rod, repeating Step 4. The car should look like the photo below.

Activity 2: Ramp-Powered Car

6) Once the last axle clip is on, you can spread the two yellow connectors apart, as shown below. Congratulations! You've finished one end of the frame.



7) Repeat steps 4 through 6 to install the other red axle rod and pair of wheels, as shown below.

8) Now add some cross-braces made from two short, white bars and four red connectors. (Refer to the photo of the completed car in Step 1.) You're all done! It's time to test your car.

Activity 2: Ramp-Powered Car

Activity 2: Ramp-Powered Car - Test Results Table

Test #	Distance (inches)	Time (seconds)	Speed (inches/sec)	Notes
Example:	10	2	10 ÷ 5 = 2	Changed design to improve...
1				
2				
3				
4				
5				
6				
7				
8				
9				
10				
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12				
13				
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15				
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18				
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20				

Activity 3: Rubber-Band-Powered Car

Name: ______________________________ **Date:** ____________

Engineering Design Challenge

When engineers create a new design, one of their first tasks is to understand the restrictions that are imposed by the nature of the product and its purpose. For example, an automobile they design must be narrow enough to fit in one lane on the road and it may be required to run on 87-octane gasoline. These specifications and restrictions are referred to as "design constraints."

For today's design challenge, you are to develop a rubber-band-powered car using the materials in the K'NEX® Motion and Design Set provided by your instructor.

Your instructor will tell you your design objective.

Optimize your design to best achieve the given objective within the following design constraints:

1. Wheelbase must be 3.5" to 17.0" (distance between the front and rear axles).
2. Length must be 4.5" to 21.0".
3. Width must be 2.25" to 5.5".
4. Maximum height is 8.0".
5. Band-mount cross-brace rod must be 1.75" +/- 0.25" above surface of the road.
6. Band-mount cross-brace rod must be no less than 3.5" from the rear axle.
7. Car is to be powered by one size #16 rubber band

Record your test results in the table. (Some of the items in the table may not apply to the type of testing that you are doing.) Remember to keep notes about the various test-runs.

Activity 3: Rubber-Band-Powered Car

Activity 3: Rubber-Band-Powered Car - Test Results Table

Test #	Distance (inches)	Time (seconds)	Speed (inches/sec)	Crossbar to Drive Axle (inches)	Notes
Example:	10	2	$10 \div 2 = 5$	2	Changed design to improve...
1					
2					
3					
4					
5					
6					
7					
8					
9					
10					
11					
12					
13					
14					
15					
16					
17					
18					
19					
20					

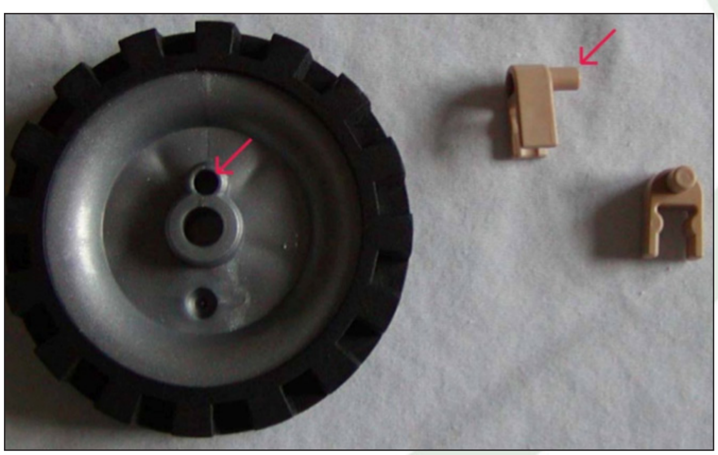
Activity 3: Rubber-Band-Powered Car

Rubber-Band-Powered Car - Prototype Instructions (Optional)

1) These instructions assume that you have already built the ramp-powered car from Activity 2. You are going to modify it so that it is propelled by a rubber band.

Prototype of Rubber-Band-Powered Car

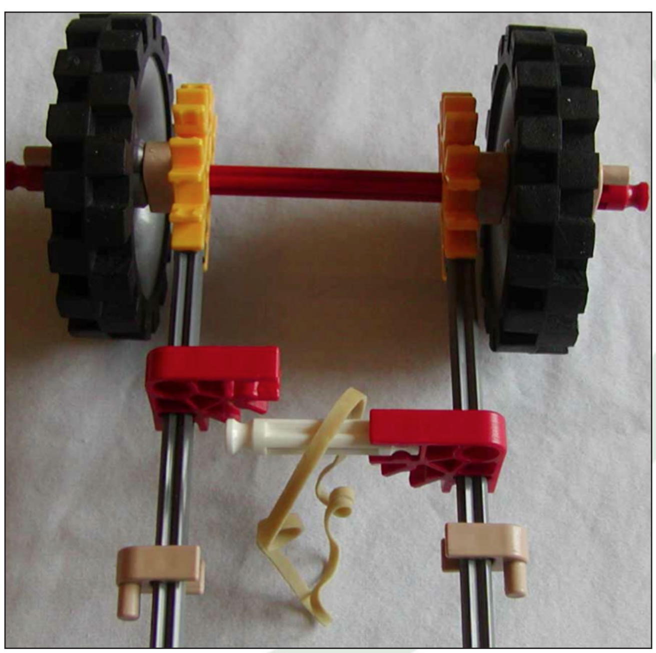
2) Remove one of the red axles by removing the wheels and sliding it out of the yellow connectors. Notice in the picture below that the tan axle-clip has a locking tab (see red arrow on the right) that can fit into a hole (see red arrow on the left) in the wheel hub. This allows the drive wheels to be connected to the drive axle so that they all turn together.



Activity 3: Rubber-Band-Powered Car

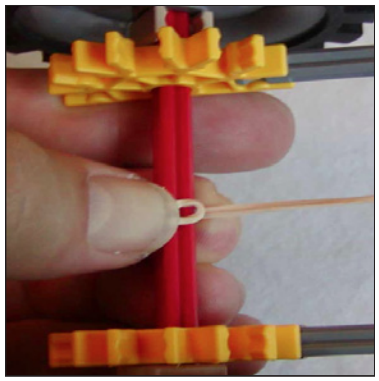
3) The picture below shows one of the wheels on the red axle with the new axle-clip configuration. Note that when the tan clip slides over, its locking tab will fit into the hole in the wheel hub. It is important that the tan axle-clips on the drive axle NOT have their locking tabs fitted into the yellow connector because this would prevent the drive axle from turning. Re-install the red axle after you have finished modifying it so that both drive wheels are connected to the drive axle using the tan clips.

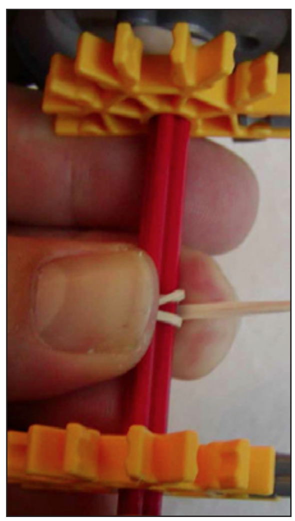
4) Install the rubber band by taking apart the cross-brace (red connectors and white rod) that is farthest away from the drive axle and sliding the rubber band around it, as shown below. Note the clips on the gray rod—they are added so that the red connector does not slide when the rubber band is wound up.

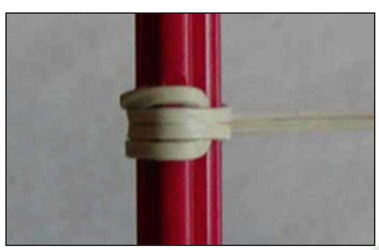


Activity 3: Rubber-Band-Powered Car

5) Your modifications are finished. Time to wind it up! Stretch the free end of the rubber band and hold it tightly against the drive axle. Continuing to hold the rubber band, rotate the drive axle backward until the rubber band begins to overlap itself (see photos below). Let go of the rubber band and continue rotating the axle. When the band is fully wound, set the car down and let it go.







Activity 4: Propeller-Powered Car

Name: ______________________________ **Date:** ______________

Engineering Design Challenge

When engineers create a new design, one of their first tasks is to understand the restrictions that are imposed by the nature of the product and its purpose. For example, an automobile they design must be narrow enough to fit in one lane on the road and it may be required to run on 87-octane gasoline. These specifications and restrictions are referred to as "design constraints."

For today's design challenge, you are to develop a propeller-powered car using the materials in the K'NEX® Motion and Design Set provided by your instructor.

Your instructor will tell you your design objective.

Optimize your design to best achieve the given objective within the following design constraints:

1. Wheelbase must be 5.0" to 11.0" (distance between the front and rear axles).
2. Must use a combination of narrow and wide wheel hubs.
3. Hub-only wheel designs (no tires) are acceptable.
4. Length must be 6.5" to 13.0".
5. Width must be 2.25" to 5.5".
6. Maximum height is 11.0". (Propeller blades can extend above this height.)
7. Car may be powered by up to two size #16 rubber bands.
8. You may configure the rubber bands any way you like to attain peak performance.

Record your test results in the table. (Some of the items in the table may not apply to the type of testing that you are doing.) Remember to keep notes about the various test-runs.

Activity 4: Propeller-Powered Car

Activity 4: Propeller-Powered Car - Test Results Table

Test #	Distance (inches)	Time (seconds)	Speed (inches/ sec)	# of Prop Turns (turns)	Efficiency (inches/ turn)	Notes
Example:	10	2	10 ÷ 2 = 5	100	10 ÷ 100 = 0.1	Changed design to improve...
1						
2						
3						
4						
5						
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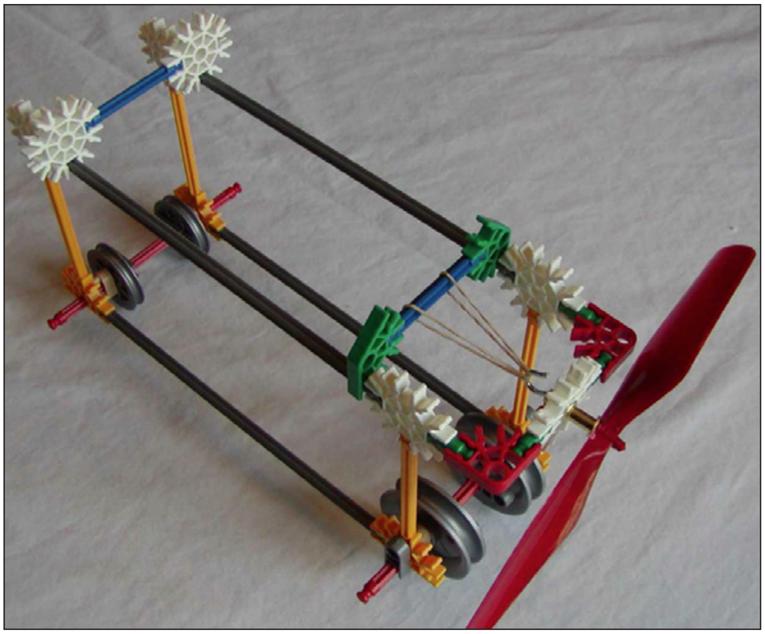
Activity 4: Propeller-Powered Car

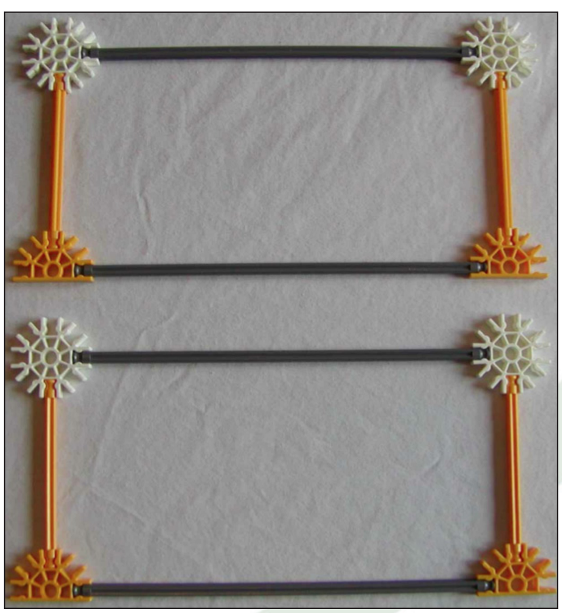
Propeller-Powered Car - Prototype Instructions (Optional)

1) A sample propeller car is shown below. On a smooth surface, this prototype was able to travel more than 3 feet when powered by two size #13 rubber bands.



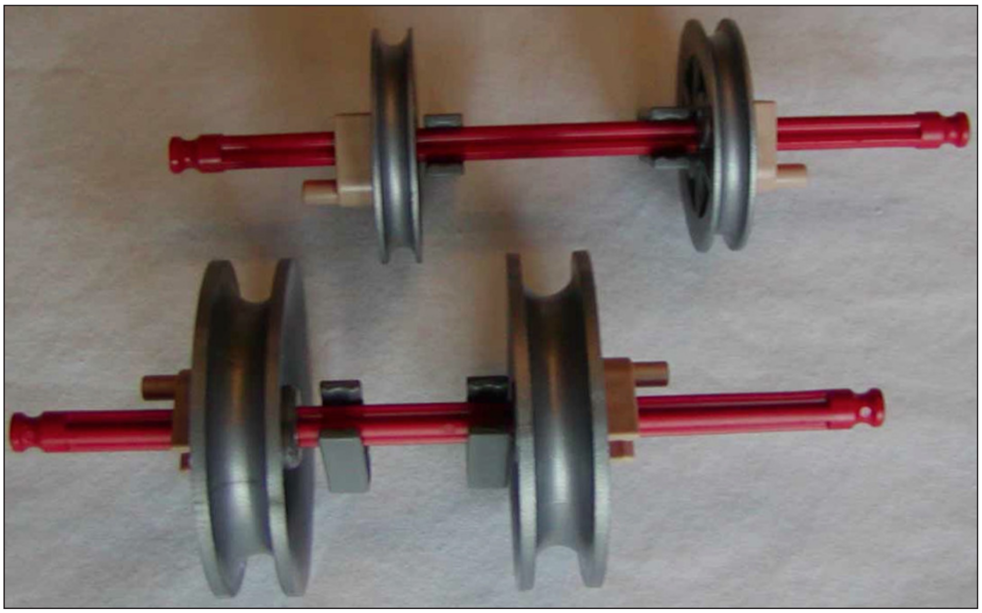
Prototype of Propeller-Powered Car

2) Begin by constructing the frame of the car, as shown below.



Activity 4: Propeller-Powered Car

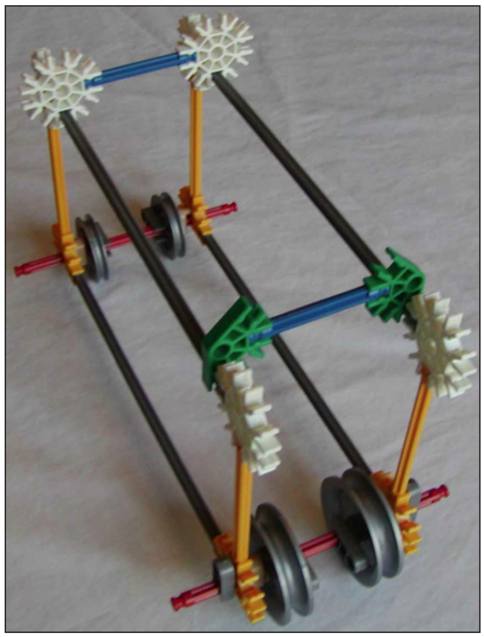
3) Now construct the two axles, as shown below. There are many ways to build a successful propeller-driven car. In the example shown here, one axle uses small wheels and the other uses large wheels. (If large wheels are placed on the axles beneath the propeller and you install tires on them, the propeller will sometimes strike the tires, reducing performance.) Note that the hub locking-tabs on the tan axle-clips are facing outward so that they can spin freely around the red axle rod. For more information about how the hub locking-tabs work, refer to Activity 3 Prototype Instructions, Steps 2 and 3.



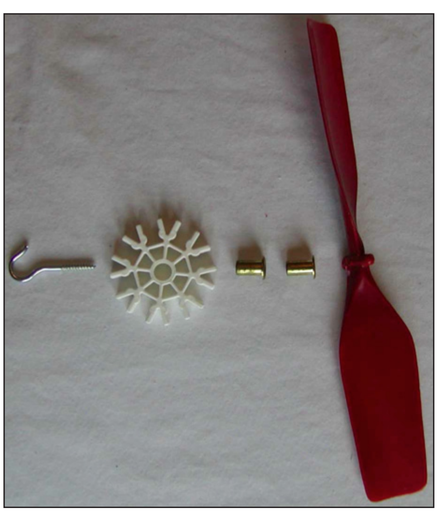
4) Slide the two sides of the frame onto both red axles. Secure one end by snapping two silver axle-clips onto the red axle outside of the yellow connectors, as shown below. (Note that the axle with the small wheels does not have the silver clips on it.)

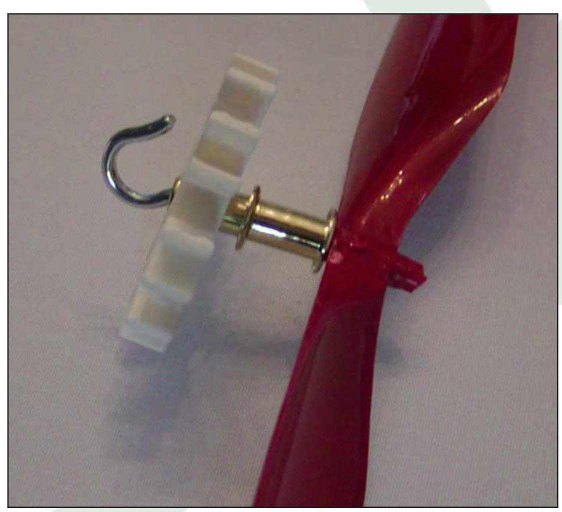
Activity 4: Propeller-Powered Car

5) Add two cross-braces to the top rails, as shown below. You can choose from several kinds of connectors (two white connectors are shown with one cross-brace, and two green connectors are shown with the other cross-brace), but you must use blue rods for the crossbars.



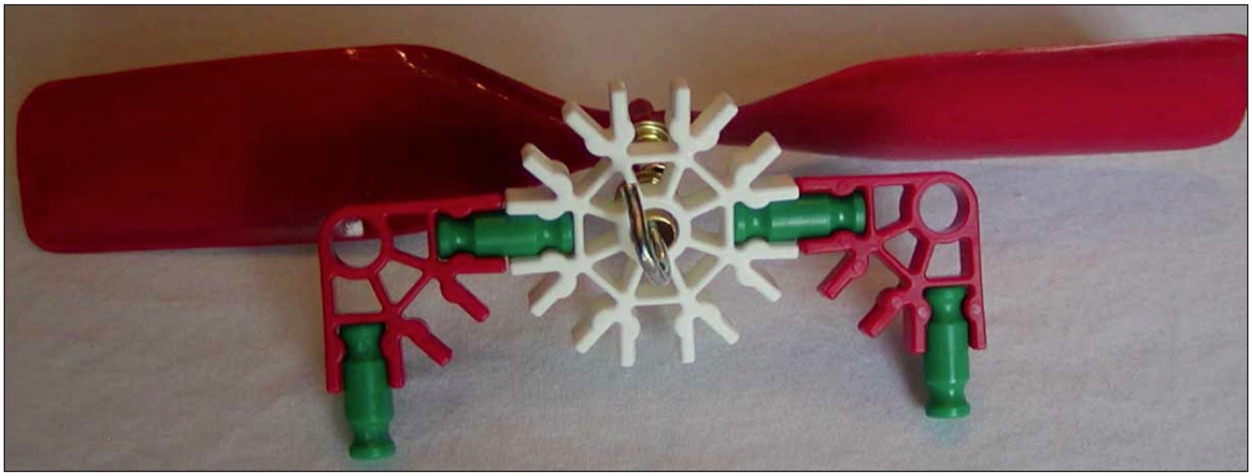
6) Your base car is complete. Now you can build your propeller. Carefully study the two pictures below. The propeller direction matters. The direction the propeller faces will determine whether the car will be pushed or pulled when the propeller turns. Make sure you don't screw the J-hook into the wrong side. The flatter end of the propeller should make contact with the brass bushing. (Note the curvature of the center area of the propeller in the picture on the right.) Also note that the wide bases of the two brass bushings face toward the propeller. One bushing fits inside the center hole of the white connector.



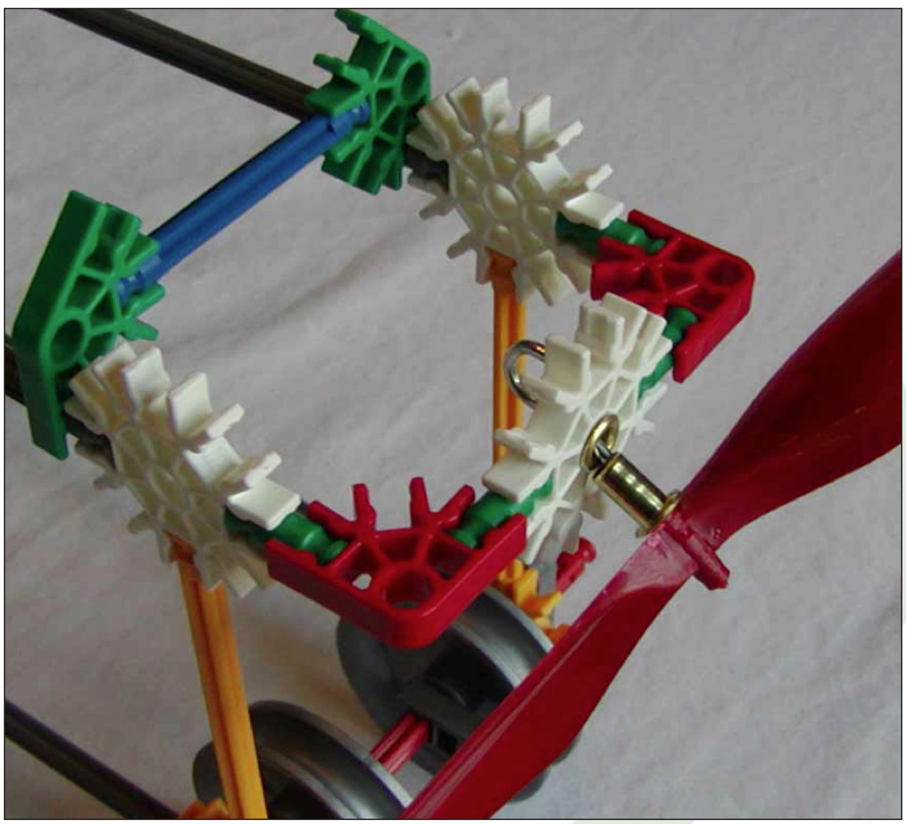


Activity 4: Propeller-Powered Car

7) Add two red connectors and four green rods, as shown below.

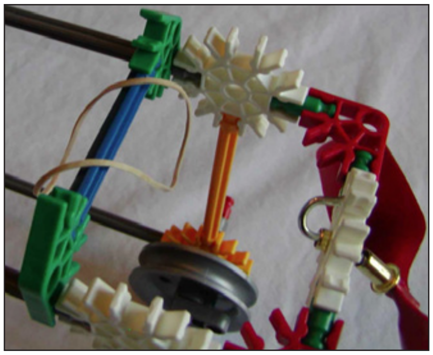


8) Attach the completed propeller section to the car frame, as shown below.



Activity 4: Propeller-Powered Car

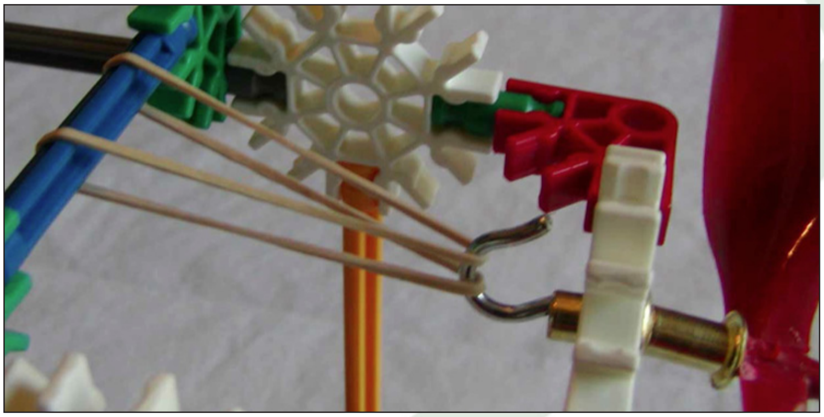
9) Mount the rubber band. First drape the band over the blue crossbar rod, as shown below.



10) Pull the loose ends under the bar and pinch them together. Stretch the ends and attach them to the J-hook (see pictures below).

11) Put on your safety glasses. Turn the propeller with your hand. This will wind the rubber band. When you're ready, let the propeller go and the car will take off.

12) To increase the engine power, you may use two rubber bands instead of one, as pictured below. Hold two rubber bands together and wrap them just as you did with the single band. Do not use more than two size #16 rubber bands. Too many bands will rip the J-hook out of the propeller, damaging and slinging parts. Always wear safety glasses when winding the bands and keep your face away from the engine area in case the bands break.



Activity 5: Balloon-Powered Car

Name: ______________________________ **Date:** ______________

Engineering Design Challenge

When engineers create a new design, one of their first tasks is to understand the restrictions that are imposed by the nature of the product and its purpose. For example, an automobile they design must be narrow enough to fit in one lane on the road and it may be required to run on 87-octane gasoline. These specifications and restrictions are referred to as "design constraints."

For today's design challenge, you are to develop a balloon-powered car made from the materials provided.

Your instructor will tell you your design objective.

Optimize your design to best achieve the given objective within the following design constraints:

1. Wheelbase must be a minimum of 8.0" (distance between the front and rear axles).
2. Must use a combination of narrow and wide wheel hubs.
3. Hub-only wheel designs (no tires) are acceptable.
4. Minimum length is 9.0".
5. Minimum width is 4.5". (No maximum given! Gray rods for axles?)
6. Minimum height is 9.0".
7. All energy for movement must come from the balloon. No more pumping is allowed once the balloon begins to press against the frame rods.

Record your test results in the table. (Some of the items in the table may not apply to the type of testing that you are doing.) Remember to keep notes about the various test-runs.

Activity 5: Balloon-Powered Car

Activity 5: Balloon-Powered Car - Test Results Table

Test #	Distance (inches)	Time (seconds)	Speed (inches/sec)	# of Air Pumps (pumps)	Efficiency (inches/pump)	Notes
Example:	10	2	10 ÷ 2 = 5	20	10 ÷ 20 = 0.5	Changed design to improve...
1						
2						
3						
4						
5						
6						
7						
8						
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10						
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12						
13						
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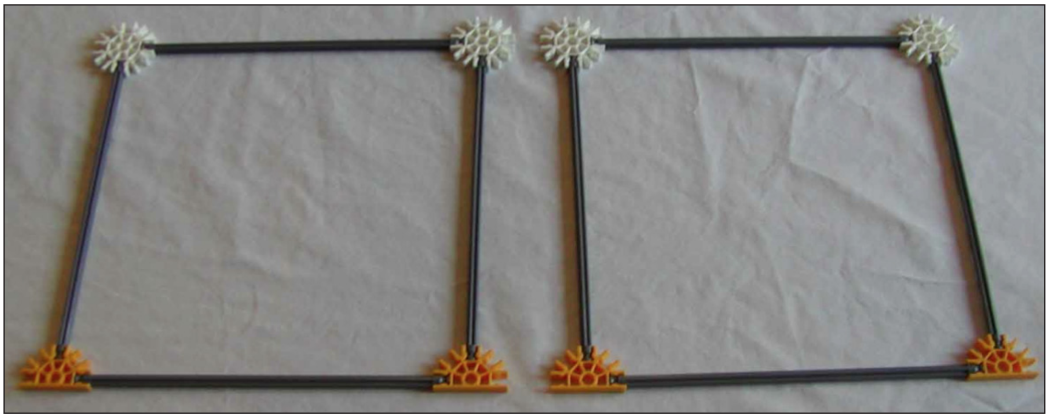
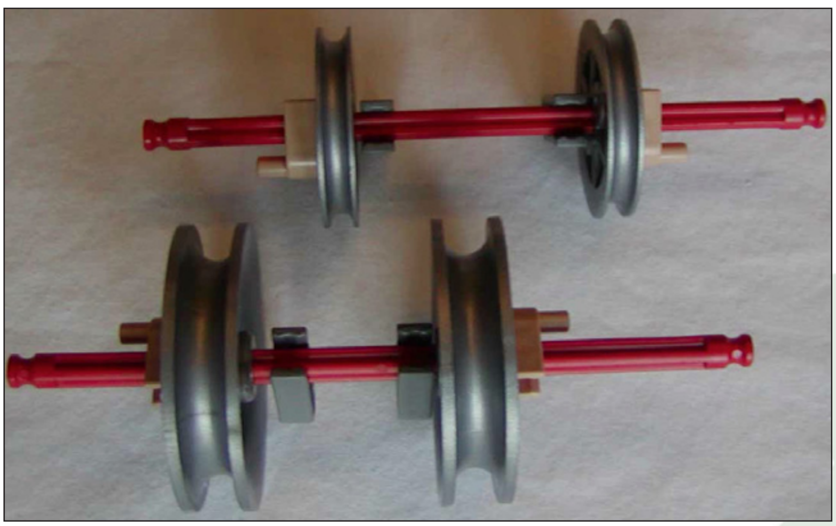
Activity 5: Balloon-Powered Car

Balloon-Powered Car - Prototype Instructions (Optional)

1) Construct the frame of the car, as shown below.



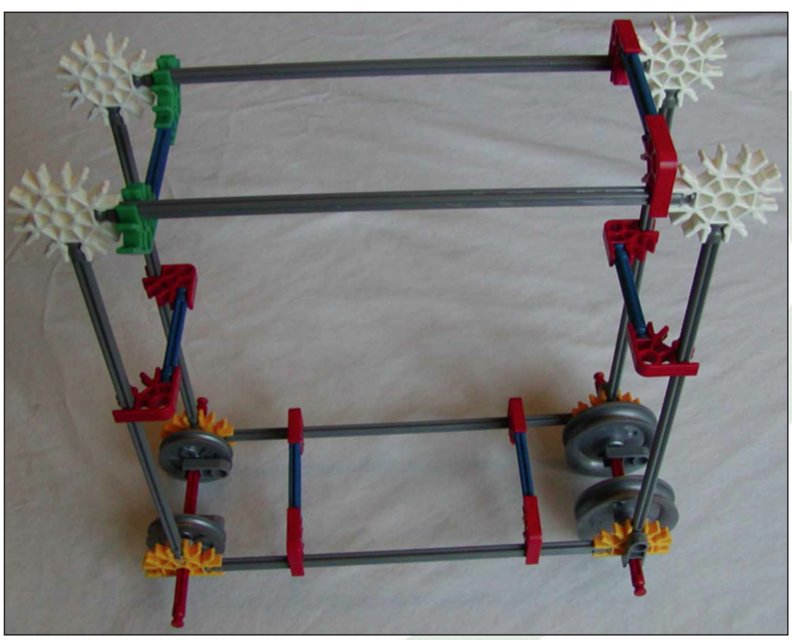
2) Build two axles, as shown below. Note that the hub locking-tabs on the tan axle-clips are facing outward so that they can spin freely around the red axle rod. For more information about how the hub-locking tabs work, refer to Activity 3 Prototype Instructions, Steps 2 and 3.



Activity 5: Balloon-Powered Car

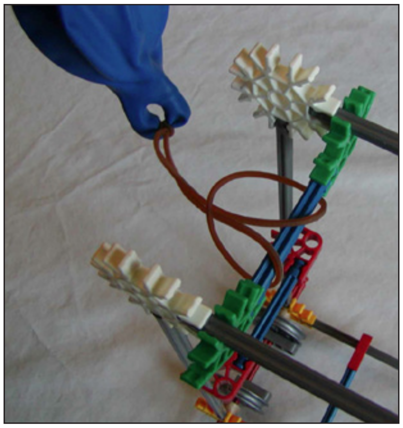
3) Slide the two sides of the frame onto both red axles. Secure one end of the frame to the large-wheel axle by snapping two silver axle-clips onto the outside of the yellow connectors. You will not use any on the axle with the smaller wheels.

4) Add six cross-braces, as shown below (six blue rods with 10 red and two green connectors). You can choose from several kinds of connectors, but you must use blue rods for the crossbars.

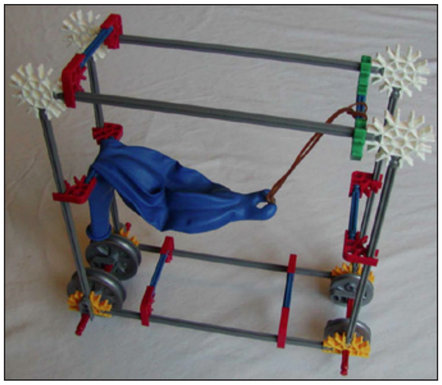


Activity 5: Balloon-Powered Car

5) Tie the punch balloon to the top cross-brace rod in the front of the car by passing the balloon through the center of its rubber band, as shown below.



6) A finished balloon car is pictured below.

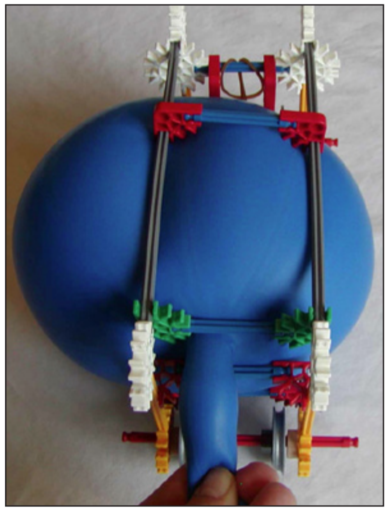


Prototype of Balloon-Powered Car

7) Now you're ready to start the car. Using the air pump, inflate the balloon while it is confined inside the frame. Stop inflating when the balloon pushes against the frame. Pinch the balloon closed with your fingers. Release your fingers when you're ready to start the car.

Activity 5: Balloon-Powered Car

8) It's good to be creative in your design, but be careful about confining the balloon in a space that is too small. One engineer's early design is shown below. Notice how the balloon puts a lot of stress on the gray rods, causing the frame to bend. The car had to be redesigned to use only gray rods in the frame so the balloon would have more room to expand. **Engineering design involves trial-and-error, no matter how experienced you are.**



Avoid designs that confine the balloon too much!