Newton's Second Law
Knex cars

Vanderbilt Student Volunteers for Science

2018-2019 VINSE/VSVS Rural

Training Presentation

Important!!!

- Please use this resource to reinforce your understanding of the lesson! Make sure you have read and understand the entire lesson prior to picking up the kit!
- We recommend that you work through the kit with your team prior to going into the classroom.
- This presentation does not contain the entire lesson—only selected experiments that may be difficult to visualize and/or understand.

I. Background Information

- **Newton's Laws** are laws which describe the motion of a body when a force acts on it. There are three laws:
  - **1st Law:** An object in motion stays in motion unless acted upon by a force and an object at rest stays at rest unless acted upon by a force
  - **2nd Law:** The force applied by an object is equal to the object's mass times its acceleration
  - **3rd Law:** For every action there is an equal and opposite reaction

III. Newton's 2^{nd} Law of Motion

- Write the following equations on the board:
  - Force = mass * acceleration
  - V = D/t
  - A = Final v – starting V/Final t – starting t

    = Final V – 0/Final t – 0

    = D/t/t

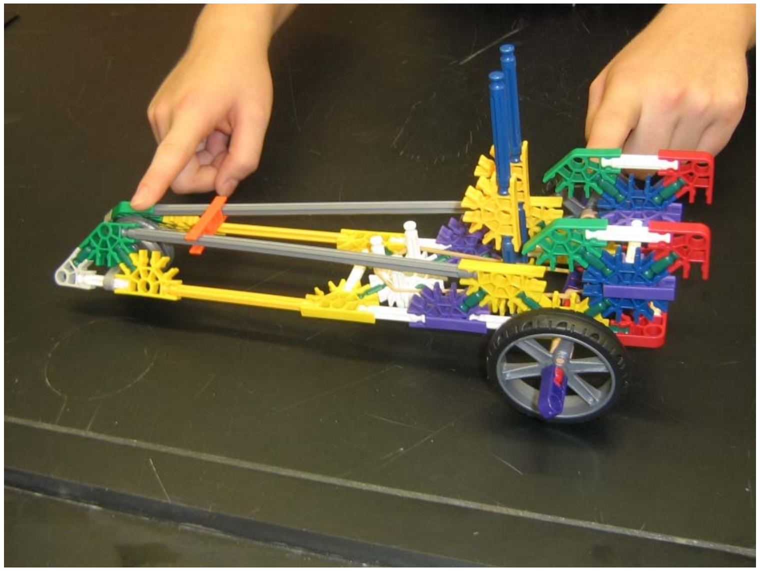
    = d/t^2
- Tell the students that these equations help relate acceleration with mass. They will examine how changing the mass of the cart, will affect it's acceleration and the **time** it takes to travel a certain distance.

Introduction (cont.)

- **Make a Prediction**
  - Have the students use the equation above to predict what they think will happen in the experiment in terms of the variables.
  - When the input force INCREASES and the mass is held CONSTANT, the acceleration of the car will ________________.
  - When the mass of the car INCREASES and the input force is held CONSTANT, the acceleration of the car will _______________
- **Visual Demonstration (Optional)**
  - If there is a chair with wheels in the class, bring it to the front of the room.
  - Ask a smaller student to sit in the chair and have another student push it with a somewhat constant force.
  - Now, have a larger/taller student or two students sit in the chair and have the same student as before push the chair again with the added mass.
  - Discuss the results with the class using terms from the prediction.

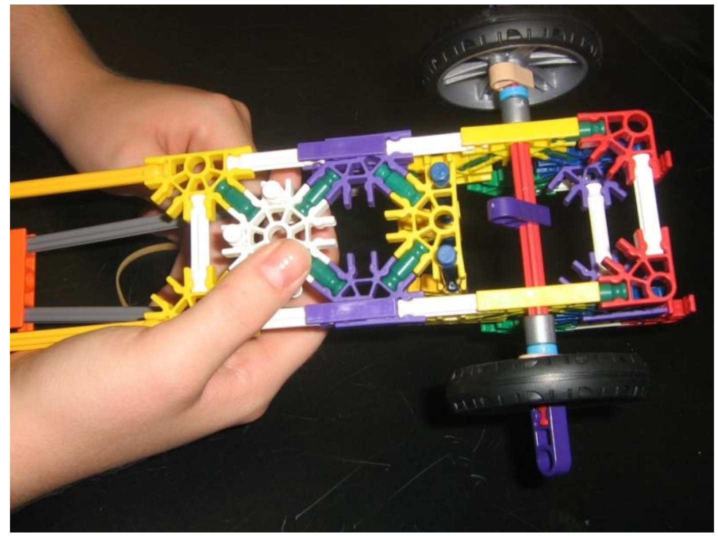
Materials for Each Group

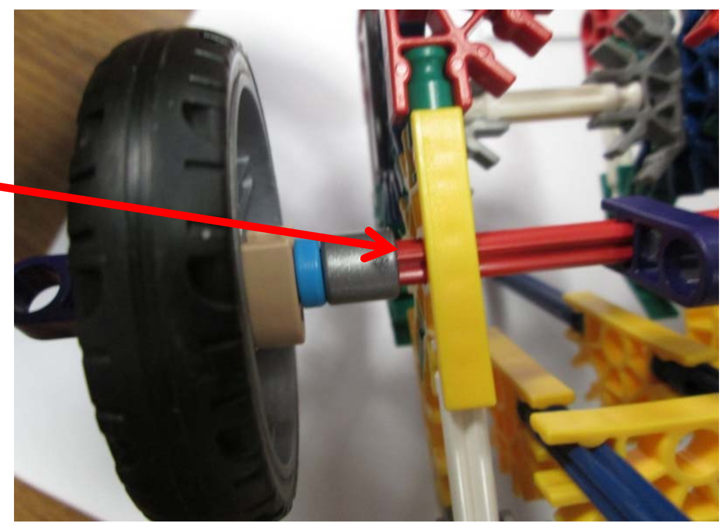
- Each group should receive the following materials:
- K’nex car
- 6 washers
- Extra rubber bands
- Stopwatch
- Tape measure



Setup/Test Run

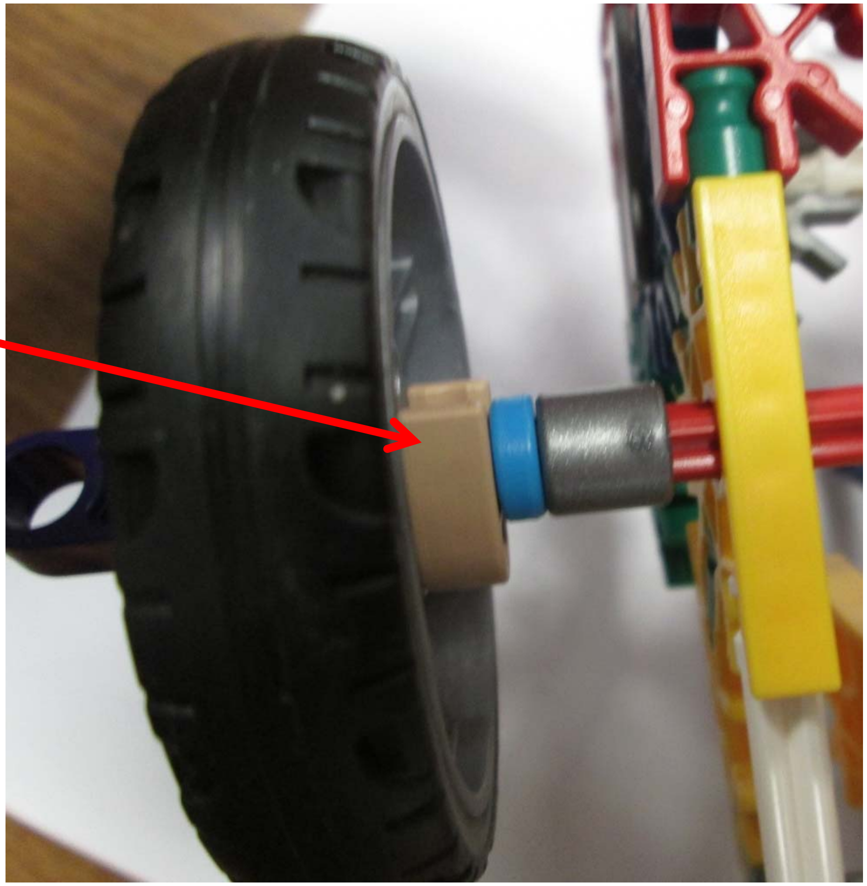
- Make sure all wheels rotate freely by flipping car over and manually rotating wheels
- If not, make sure wheels are not rubbing against the sides of the car





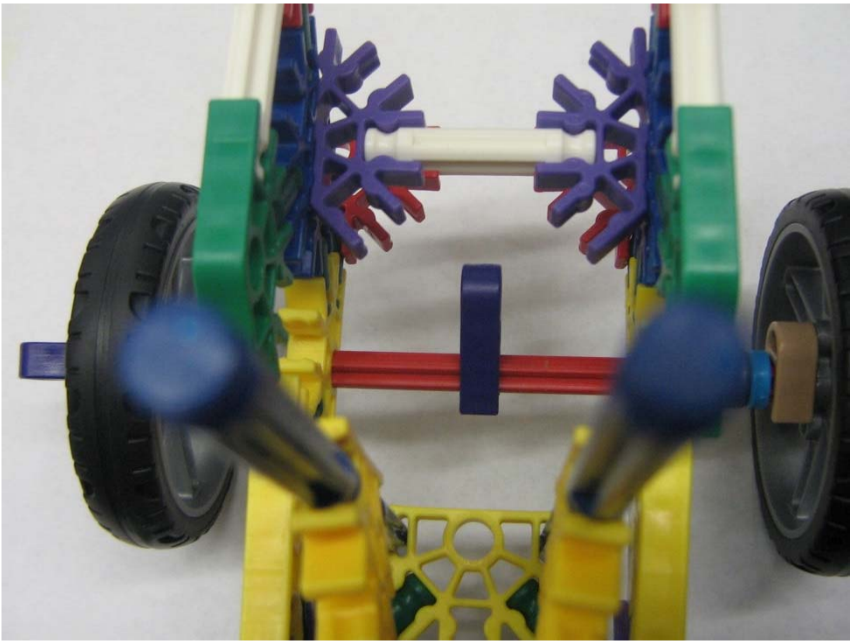
Setup/Test Run

- Sometimes the clips holding the wheels become loose (see picture)
- Fix this by inserting the pin into the hole seen in the frame of the wheel as show in the picture



Setup/Test Run (cont.)

- Make sure the rubber band holder is centered on the axle (rotating shaft connecting wheels)



Set-up

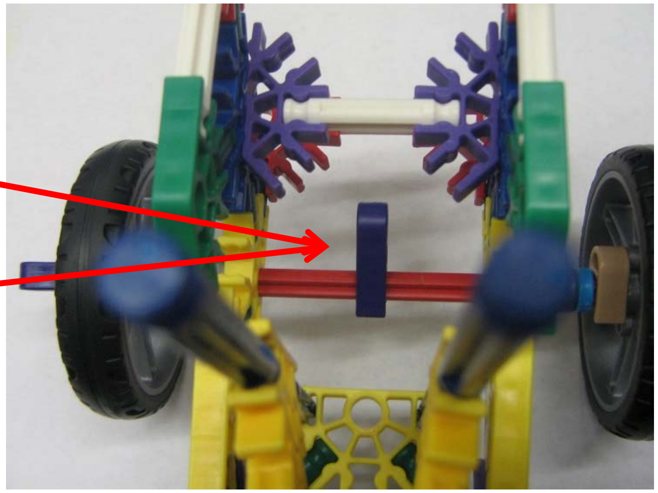
- Mark a start line with a piece of masking tape, or by some other means.
- Mark a finish line 2 M from the start.
- All team members put on their safety goggles.
- A new rubber band should be used. The rubber bands lose their elasticity after a few windings
  - **Do not place used rubber bands back into the kit. Hand them to teacher.**

Experiment 1: Varying the Force

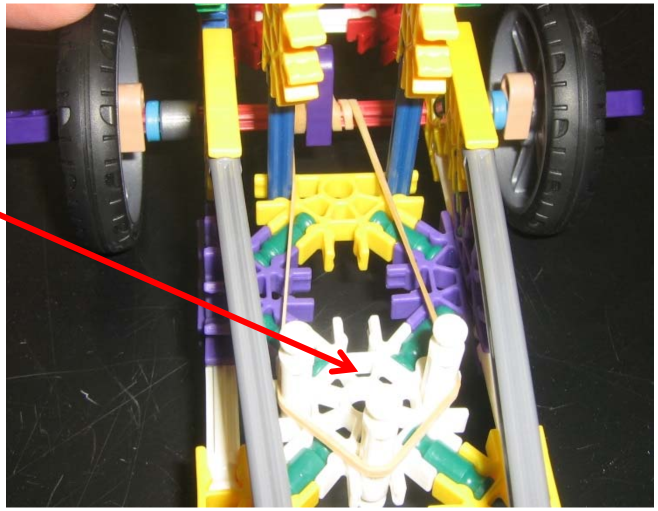
- F=ma
- The Force is changed by changing the number of times the rubber band is wound around the axle.
- Ask students which variables are held constant and which are changed?
  - Mass and distance are held constant.
  - Force is changed.
  - We are determining what happens to the acceleration by measuring the time it takes for the car to travel a set distance.

Experiment 1

- Make sure the purple rubber band holder is in the vertical position.
- Put the one end of the rubber band over the purple holder.
- Stretch it over all 3 white prongs.



- Wind the rubber band by fully rotating the wheels clockwise three times; count the number of times the purple rubber band holder makes a full rotation.
- Hold the wheels in place and place the car on the start line.
- Align the car so that its path will be straight.



Experiment 1

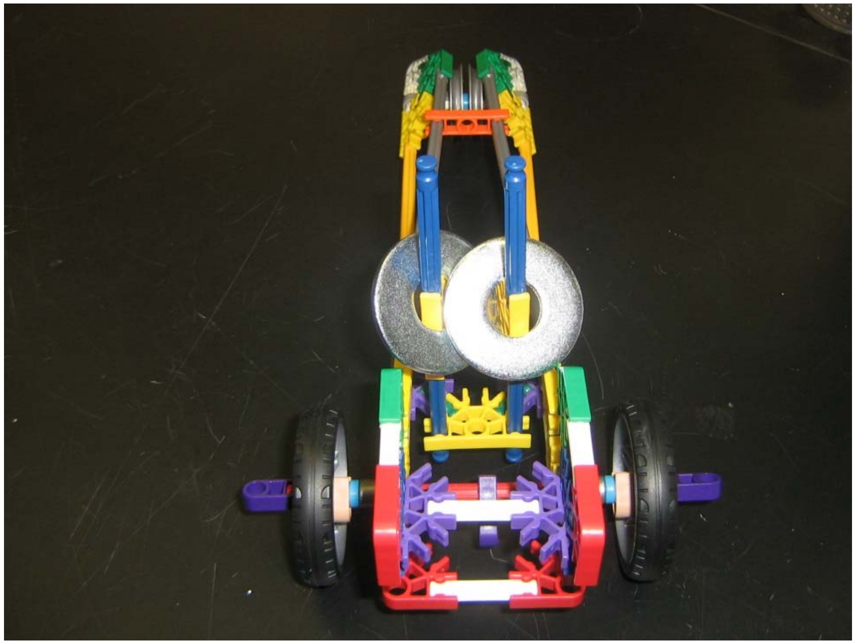
- Release the hold on the wheels and measure the time it takes for the car to travel 2m. Record data
  - Repeat the experiment two more times and take an average of the times recorded.
- Now change the number of times the rubber band is twisted to 2 rotations and repeat experiment.
- Now change number or twists to 3 then 4 full rotations and repeat.
- Calculate velocity and acceleration and plot the data.
- Draw a best-fit line for your points after they are plotted.

Experiment 2
Changing the Mass of the Car

- In this set of experiments, the only variable is the mass of the car plus added masses.
- Force is kept constant by twisting the rubber band **only three times.**
- Use fresh rubber bands as needed (after adding 4 washers and then 8).
- Note that the mass of the car is about 155gm, and is written on the orange bar on each car. The mass of each washer is written on it.

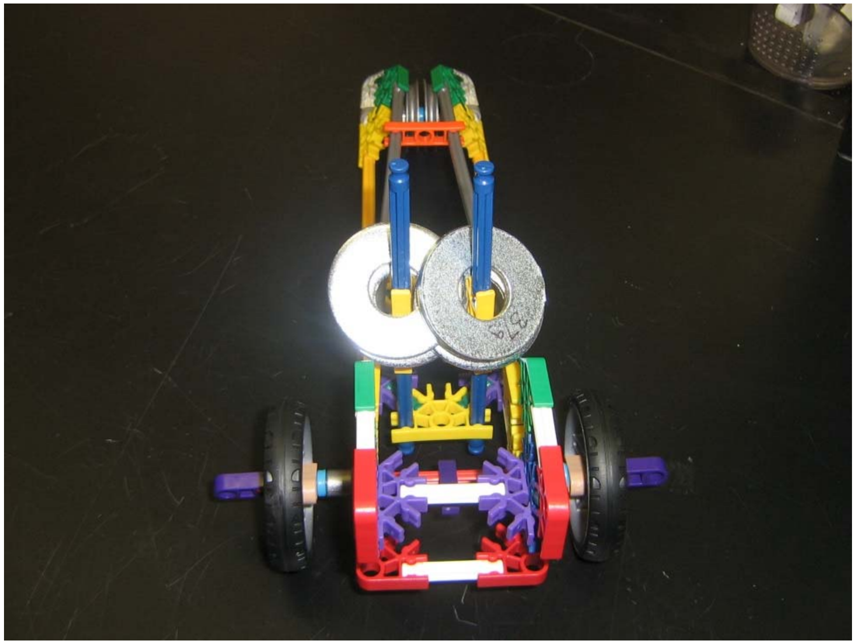
Experiment 2 contd.

- Add two washers to the holders located on the center of the car
- Record the total weight of the car (including 155gm for the mass of the car).
- After adding the weights, repeat the experiment.
  - Repeat experiment two more times and average the data and record it



Experiment 2. contd

- Now add two more washers to the holders, one to each side, for a total of four washers and repeat the experiment
- After testing four washers, the rubber band might need to be replaced
- Now add two more washers, one to each side for a total of six, and repeat the experiment.
- Average the times recorded.
- Calculate the velocity and acceleration and graph the results.
- Draw a best-fit line for your points after they are plotted.



IV. Calculations and Graphing.

- Have the students predict (from their graphs) what the values for a trial using
  - Another turn of the rubber band.
  - Adding another 2+ washers.
  - Adding another rubber band to the axle

Sample Graphs and Questions

- Look at the graphs. What can you infer about the relationship between increasing input force with constant mass? about increasing mass with constant input force?
- What happened to acceleration in each part of the experiment?

Experiment 3 – Optional.
Changing the force by changing the # of rubber bands.

- Another way to increase the Force is to increase the number of rubber bands from those used in Experiment 1.
- Replace the 1 rubber band with 2 fresh ones.
- Repeat the experimental steps and
- record the data.

Conclusions

- From the linearity of the graphs, students will see that as input force increases and mass is held constant, then the distance the plastic cup travels increases as well.
- When the mass increases and the input force is held constant, the distance traveled by the plastic cup will decrease.
- Distance is a factor in acceleration, which is measured in (m/s^2).
- Mass and input force both affect the distance the cap is able to travel.
- The last question regarding Newton’s First Law of Motion refers to friction. Friction is the force that slows or stops objects from being in motion. Air resistance could also be a correct answer, but in this particular experiment, air resistance, as well as friction, is neglected.
- The main idea is that stronger input forces will result in greater accelerations, while adding mass will result in smaller accelerations.

III. Newton's 2nd Law of Motion

- Ask the students what relationship do they see between mass v. acceleration and mass v. time. In other words does the time it takes the cart to travel increase as mass increases?