SCIENCE, TECHNOLOGY, ENGINEERING, AND MATH
COLORADO STATE UNIVERSITY EXTENSION

ST[EMpower]

CAREERS

We have been exploring career ideas over the past 3 months. If you missed those issues, you can find activities 38 through 40 located here: http://tra.extension.colostate.edu/stem-resources/

The 12 broad interest categories are:

- Adventure
- Animals and Nature
- Art
- Business
- Computers
- Math
- Music and Dance
- Science
- Sports
- Talking
- Travel
- Writing

What are your four top ranked broad interests from the results of your quiz:

1.

2.

3.

4.

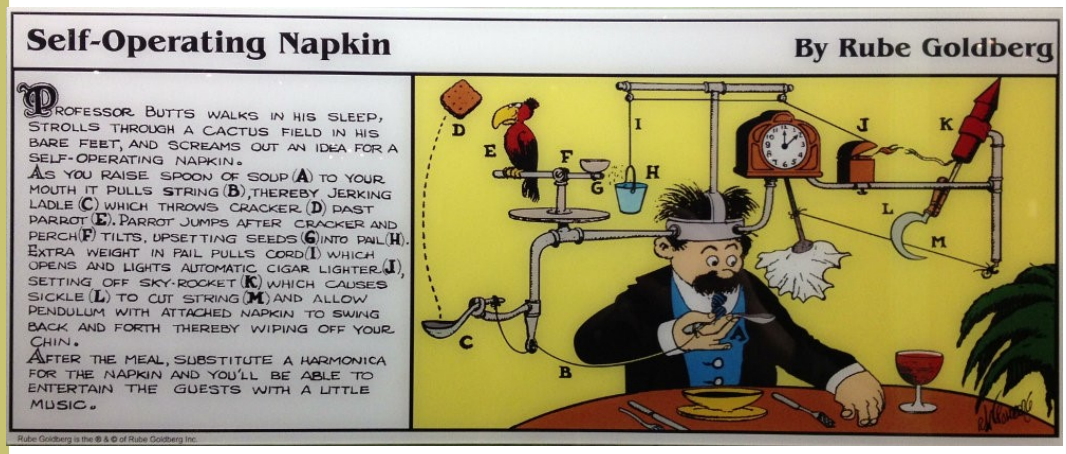
Last month, you worked on a project that combined your top interests. The project you selected also reviews your interests.

- Selecting your favorite TV shows, movies, and books, The TV shows and movies you watch, the books you

Rube Goldberg Machines!

Wacky Fun!

Dr. Barbara J. Shaw



BACKGROUND

Rube Goldberg (1883-1970) was born in San Francisco on July 4th, 1883. He graduated from the University of California Berkeley with a degree in engineering, but he realized that engineering was not the career for him. His first job at the San Francisco Chronicle led to early success. He moved to New York City to work for Hearst publications. That is when he became a household name. He was a Pulitzer Prize cartoonist, and he is best known for his zany invention cartoons, like the one above. He is the only person to be listed in the Merriam Webster Dictionary as an adjective. It's estimated that he developed a whopping 50,000 cartoons in his lifetime. (From Rube Goldberg, Inc.: https://www.rubegoldberg.com/about/)

Objectives

You will:

- Identify and describe Sir Isaac Newton's Three Laws of Motion
- Build and explain how the Simple Machines function
- Construct a Rube Goldberg Machine utilizing the Three Laws of Motion and Simple Machines

DO:

Materials:

- Plastic cup half full of water
- Coins (3 quarters, 1 dime, 1 nickel, and 1 cent)
- Corrugated cardboard

- Die cast small toy car (e.g. Matchbox or Hot Wheels)
- Marbles
- Books—at least 3—thicker the better
- Ruler
- Scissors
- Pull-back car
- Paper
- Pencils at least 2—rounded work best
- Masking tape
- Rolling pin
- Twine or rope (about 6-8')
- Toilet paper tube
- Hard boiled eggs 3
- Dowel 12"
- Tubing (about 24" - purchase from the pet store)
- Bowls 2
- Balloons

Note: Everything that moves on Earth follows the Three Laws of Motion. Testing the three laws of motion is endless fun! The activities included in this lesson are for easy demonstration only. There are millions of ways to explore (like a good game of baseball, or swimming, or playing jacks or marbles or…)

Three Laws of Motion: First Law—Inertia

An object at rest will remain at rest unless acted on by an unbalanced force. An object in *motion* continues in *motion* with the same speed and in the same direction unless acted upon by an unbalanced force.

Object at Rest

- Fill the plastic cup at least half full of water.
- Cut a square piece of cardboard a bit larger than the cup.
- Place the cardboard on top of the cup and a quarter centered over the cup on top of the cardboard.
- Predict what will happen when you flick the cardboard with your thumb and index finger so that the card goes straight off the top of the cup.
- Flick the card. What happened?
- Repeat this with a nickel. Predict and then flick.
- Repeat with a cent. Predict and then flick.
- Repeat with a dime. Predict and then flick.
- Stack all the coins with the quarter on the bottom. Predict and flick.
- Stack all the coins with the dime on the bottom. Predict and flick.
- Explain what happened to the coins.
- *The coins are at rest and they remain at rest. When the card is flicked away, gravity pulls them down into the cup. If you flick the card too slowly, the lighter coins may move because friction (another force) will start to pull them with the card.*

read are very telling about your interests. Keep in mind that you may also be drawn to art.

- If you selected writing a story, then you are interested in writing. The story itself is revealing about other interests.
- If you selected designing something using recycled materials, then you also have an interest in art, science, or math.
- If you selected the journal, then you have an interest in writing and math. (Isn't it funny how some interests in math seem so un-math-y?)
- If you presented activities to younger 4-H members, then you also have an interest in talking.

Are you surprised at what you selected? Did you pick something that falls into your top ranked interests, or did you pick something that was outside those interests?

This month, reflect:

- What you did
- How you did it
- What was successful
- What you would change
- Did you have fun?

Spend some time really analyzing your project.

- What aspects of your project were the easiest for you to do? List those.
- What skills do you have that made that part of the project easy to do?
- Which interest was dominant in your project? For example, if you made art out of recycled material, and science is one of your top

interests, did that influence what you made? Did you focus your art project on scientific aspects (e.g. selecting colors that you change with the light, or including motors and gears to make your art move)?

- Start an interest journal this month (if you didn't start it last month). Writing sparks different parts of the brain than typing does. If you utilize both writing and typing, you will be able to discover more about yourself.
- In your journal, keep things that you find interesting. For example, you see a beautiful sunrise, and you want to capture the feeling, take a picture and write a haiku in your journal. Print the picture and tape it next to your haiku.
- If you see something on the internet that is fascinating or peaks your interests, print it and tape it in your journal.
- Write your thoughts about yourself at the end of the day or first thing in the morning. Try different questions, like: Why is my favorite color red? When is my favorite time of the day?
- Don't examine the journal just yet. Right now, your are just gathering those things that please you, spark your interest, or fascinate you.
- Have fun!

Object in Motion

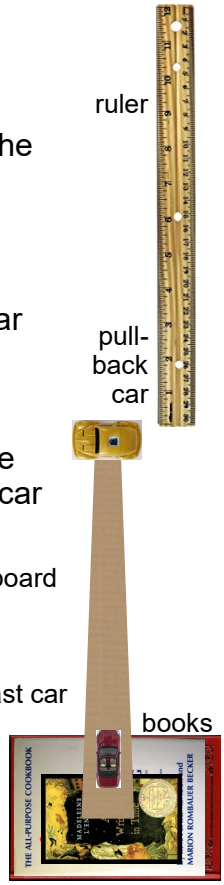
- I am Aroldis Chapman, a pitcher for the Cincinnati Reds, and I have the record fast pitch of 105.1 mph. I am on the International Space Station and doing a space walk. I have a baseball in my hand. I anchor myself to the space station, and face away from the Earth. I throw the ball as hard as I can away from the Earth. What happens to the ball?
- *The ball will continue traveling in a straight line at 105.1 mph forever, unless it gets too close to another object (like a planet). The gravity from that planet will pull the ball away from the straight line, and probably slow it down some. If a bit of space debris hits the ball, the impact will change the course and speed.*
- Make a ramp with the corrugated cardboard as long as possible (depending on the piece of cardboard you have). Make the ramp wide enough so that you can roll your cars (both the die cast car and pull-back car) down it. You can optionally make a rim on the sides to keep the car from rolling off the ramp.
- Set the ramp on three books (not the chair as pictured).
- Place a coin or marble on top of the car. If your car is a convertible, you can use the marble. If not, you can place a coin on the top of the car.
- Hold the ruler at the end of the ramp, so that the car will smack into it and stop abruptly.
- Predict what will happen to the marble or coin when the car hits the ruler.
- Try it out! Try different ramp heights.
- What happened? Why?
- *The marble or coin on top of the vehicle is traveling at a constant speed when it hits the ruler. It continues at a constant speed. There are two forces that act on the marble or coin. The first is gravity, dragging it down. The second force is collision with air molecules, slowing the marble or coin down. What would happen if you tried this one in space?*

<u>Three Laws of Motion: Second Law—F=ma</u>

The acceleration of an object as produced by a net force is directly proportional to the magnitude of the net force, in the same direction as the net force, and inversely proportional to the mass of the object.

- The formal description of the second law is crazy hard to understand, but you already understand it, because you use it every day The description is F=ma. If I have a turkey baster, and I fill it with water. I hold the baster so the bulb is

down and the tip is pointed up. What happens to the water if I slowly squeeze the bulb? What happens if I squeeze the bulb hard and fast? Yep, you already understand it.
  - "F" is the force you apply to the turkey baster bulb
  - "m" is the mass of water, and that remains the same
  - "a" is the acceleration, and that is different depending on how hard you squeeze
- It will dribble out if you slowly squeeze (low force, low acceleration), but if you really squeeze hard, the water will go flying out (high force, high acceleration). Easy Peasy!
- What happens when mass is different? You have a baseball and a bowling ball. You use the same force (throwing it as hard as you can), which will go further? The baseball, of course. The bowling ball is too heavy. So if the mass goes up, the acceleration goes down if the force remains the same. Also easy peasy! (Don't you LOVE math and science!)
- You need the die cast toy car, the pull-back car, the ramp, a ruler, the coins, the books, pencil and paper.
- As the ramp goes up, the acceleration of the die cast car will increase.
- When we add coins to the die cast car, the mass will increase. Tape the coins on so they don't go flying.
- Set up your experiment for 6 trials, and you only change one variable (height of ramp in Trials 1-3, and mass of car in Trials 4-6):
  - Trial 1: Lowest ramp no coins
  - Trial 2: Middle ramp no coins
  - Trial 3: Highest ramp no coins
  - Trial 4: Middle ramp, 1 quarter taped down
  - Trial 5: Middle ramp, 2 quarters taped down
  - Trial 5: Middle ramp, 3 quarters taped down
- Set up your ramp with the pull-back car at the bottom of the ramp, so that your die cast car will run into the side of it. You will measure how far the die cast toy car pushes the pull-back car depending on the mass of the car and the acceleration of the car. How far the pull-back car is pushed is the force. Record the distance with each of your six trials.
- Graph your results, and explain what happened.



Three Laws of Motion: Third Law—Action/Reaction

For every *action*, there is an equal and opposite *reaction*.

- The Third Law of Motion is how forces act on objects as they start to move. A frog is sitting on a lily pad, and hops to a nearby lily pad. What happens to the first lily pad as the frog jumps?
- You and your friend are each standing on skateboards facing each other. You push your friend away from you. What happens to you on your skateboard?
- In both instances, the lily pad and your skate board move in the opposite direction of the jump/push with as much force as was applied on the jump/push. Crazy fun!

POWER WORDS

- **acceleration**: increase in the rate or speed of something.
- **force**: an influence changing the motion of a body or produce motion or stress in a stationary body; magnitude of such an influence is calculated by multiplying the mass by acceleration.
- **inclined plane**: a plane inclined at an angle to the horizontal.
- **lever**: a rigid bar resting on a pivot, used to help move a heavy or firmly fixed load with one end when pressure is applied to the other.
- **mass**: the quantity of matter that a body contains, as measured by its acceleration under a given force or by the force exerted on it by a gravitational field.
- **pulley**: wheel with a grooved rim around which a cord passes; acts to change the direction of a force applied to the cord and used to raise heavy weights.
- **Rube Goldberg machine**: a deliberately complex contraption in which a series of devices that perform simple tasks are linked together to produce a domino effect in which activating one device triggers the next device in the sequence.
- **screw**: inclined plane wrapped around a pole.
- **wedge**: portable inclined plane to separate two objects, lift up an object, or hold an object in place.
- **wheel and axel**: wheel attached to smaller axle; these two parts rotate together; the force transfers from one to the other.

FASCINATING FACTS

Sir Isaac Newton

- Sir Isaac Newton was born in 1643 and died in 1727.
- He is considered the father of modern science.
- He developed the mathematical formulae for the Three Laws of Motion, Gravity.
- He invented a branch of calculus.
- He improved telescopes by using a lens and a mirror instead of two lenses.
- He developed a theory that white light (i.e. sunlight) is composed of Red Orange Yellow Green Blue Indigo and Violet light (the colors we see in a rainbow).
- Even though Newton is considered the father of modern science, he practiced alchemy (which is not science).

Simple Machines

- Archimedes was the first person to propose simple machines, by discovering the mechanical advantage of a lever.
- Archimedes lived around the 3rd Century BC.
- Archimedes was the first person to understand that simple machines do not create energy, they only transform it.

Rube Goldberg Machines

- Rube Goldberg earned his engineering degree at the University of California Berkeley in 1904.
- He worked as an engineer for 6 months before deciding he wanted to be a cartoonist.
- He won a Pulitzer Prize in 1948 for a political cartoon called Peace Today.

- You need the pull-back car, marbles, and the cardboard ramp.
- Lay the cardboard ramp on the floor. Pull back the pull-back car to wind-up the wheels to the maximum. Most pull-back cars will click when the car is fully wound. Release the pull-back car on the cardboard. What happened? Measure how far the car went. Repeat several times. Does the car go about the same distance each time?
- Place the marbles in paired rows as wide and long as the ramp, on a hard floor (not carpet or a rug).
- Place the cardboard ramp on top of the marbles.
- Pull back the pull-back car and hold the wheel.
- Place the car at the start of the ramp and release the wheel.

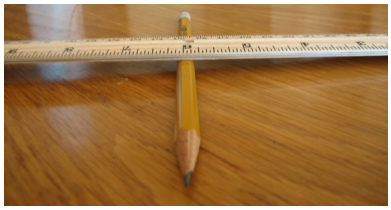

- Measure the distance the car moved. Measure the distance the ramp moved. Repeat several times.
- What happened to the car, and what happened to the ramp? Why?

Six Simple Machines

A simple machine is a device that makes work easier by magnifying or changing the direction of a force. Work (in physics) is defined as moving an object over a distance.

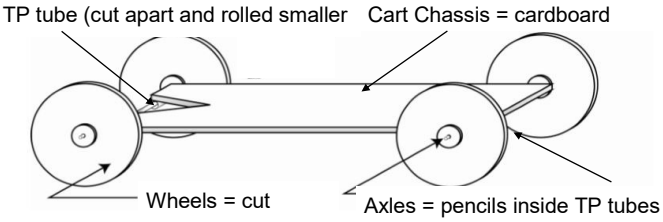
The following six activities demonstrate how the simple machines work.

- Lever
  - You need a ruler (lever), pencil (fulcrum), and a book. Place the pencil on a table and put the ruler over the pencil at the 1” mark. Place the book on 0 to 1” on the ruler. Push down on the far end of the ruler. Move the pencil to the 6” mark (pictured) with the book still on the end by 1”. Push down on the ruler again. Move the pencil to the 9” mark, and push down on the ruler again. Which pencil position was the easiest to move the book?

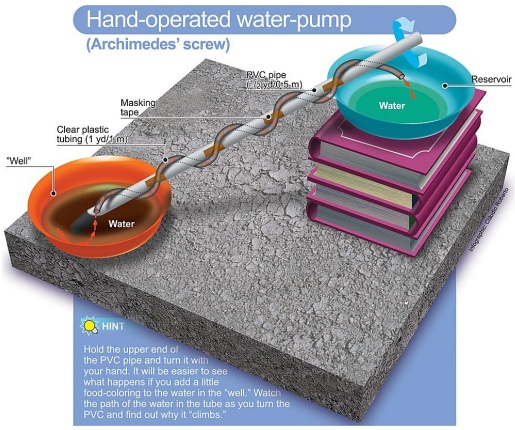


- Pulley
  - You need a rolling pin, a rope or twine (about 6’-8’ long is great), a bucket with a handle, a heavy book, and someone to help you. Tie one end of the rope to the bucket. Loop the rope over the rolling pin. Pick up the book. Ask your helper to hold the rolling pin. Place the book in the bucket and pull on the rope. Which is easier to pick up the book; with or without the pulley?
- Wheel and Axle
  - You need cardboard, 2 pencils, scissors, something with a round bottom (like a cup or jar of jam), tape, and a TP tube. Use your round object to trace 4 circles on your cardboard. Cut them out. Find the center of your circles, and poke the pencil through each of the 4 circles. Cut your toilet paper tube into two pieces. Reform a tube’s diameter slightly larger than the pencil and tape back into a tube. Cut a piece of cardboard that is smaller then the length of

the pencils. Tape the 2 TP tubes to each side of the cardboard. Insert the pencils into each tube, and attach 1 wheel to each side of the pencil. Use your book. First, drag your book across a table. Put it on your vehicle. Make sure that the book does not touch the wheels (use something to lift the book away from the wheels). Pull your vehicle across the table. Which was easier? Why?



- Inclined Plane
  - You need the cardboard ramp and three hard boiled eggs. Place the ramp at a shallow incline. Predict what will happen if you roll the egg down this ramp. Roll the first egg down the ramp. Place the ramp at a steep 45° angle. Predict what will happen if you roll the egg on the ramp to the floor. Try it. Predict what will happen if you hold the egg at the same height as the 45° ramp and drop the egg on the floor. Try it. Compare your three eggs. Were your predictions correct? What did the inclined plane do? The amount of work remains the same, but it takes less force to move an object with an inclined plane.
- Screw
  - A screw is an inclined plane that wraps around a central column. Archimedes designed a pump that would move water from the irrigation canal to the field. You need a 12" dowel and tubing (from the pet store), tape, a couple of books and 2 bowls. Spiral the tubing around the dowel, and secure with tape. Place water in one of the bowls. Place the water bowl at a lower level than the empty bowl. Place the Archimedes Screw into the lower bowl, and hover it over the upper bowl. Turn the screw so that end of the tubing in the water twists up out of the water. Keep turning the dowel and the water will move from the lower bowl to the upper bowl. How did this work?



- Wedge
  - You need a pair of scissors and a piece of paper. Cut the paper. Scissors are a combination of 2 wedges (the blade of each arm of the scissors) and a lever (the fulcrum is the pivot point, and the blades are the work end of the lever). A needle is a wedge when you use it to sew. An axe is a wedge when you use it to cut wood.

REFLECT:

You have spent some time working through the Three Laws of Motion and Simple Machines. In the reflection section, you will plan for a simple

- Mr. Goldberg was Jewish. He published political satire during World War II. He started receiving hate mail and death threats. To protect his children, he had their last names changed to George.
- Goldberg is an adjective in the Merriam-Webster Dictionary. It means, "doing something simple in a very complicated way that is not necessary."

CITATIONS

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Turkey Baster Image https://images-na.ssl-images-amazon.com/images/I/61ybG2qfU8L._SY450_.jpg

Three Laws of Motion

Image flick: https://www.tutorvista.com/content/science/science-i/force-laws-motion/inertia.php

Image ramp: http://progressiveearlylearning.com/blog/

Image 3rd Law: https://www.youtube.com/watch?v=EUQAfajlEKs

Simple Machines

Image of wheel and axle: https://inventorsoftomorrow.com/2016/10/25/design-a-car/

Image of lever: http://science-mattersblog.blogspot.com/2011/01/simple-machines-balance-lever.html

Image Archimedes Screw: http://ptgmedia.pearsoncmg. com/images/chap1_0131856731/elementLinks/01fig09.jpg

Image Engineering Process: https://sites.google.com/a/wsps.org/ms-pawlishens-science-site/design-build/engineeringtechnology/study-guides

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task and solve it using a Rube Goldberg machine solution. The cartoon on the first page is one of Mr. Goldberg's inventions. Wacky fun!

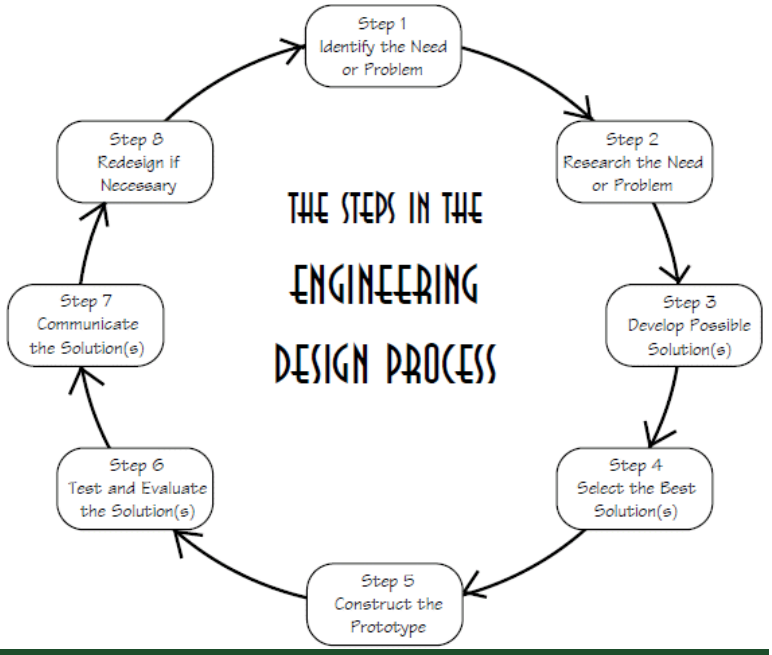
Have you ever played the game, Mouse Trap? That is a Rube Goldberg Machine. Sometimes movies have Rube Goldberg machines that crack an egg or open a gate. Not only that, but the Rube Goldberg Inc. holds a competition every year. They have wonderful videos of people solving simple problems. This year's competition is to pour cereal into a bowl. Goofy fun! https://www.rubegoldberg.com/

Your task is to build a machine that will pop a balloon in at least 12 steps using as many recycled materials in your Rube Goldberg Machine as possible (with the exception of the balloons—those should be new!).

- Consider working with a group of friends. Brainstorming with several people brings a project to a whole new level of excellence.
- Brainstorm ideas. Explore the Rube Goldberg site listed above. Not only will you find some of Mr. Goldberg's crazy invention cartoons, but you can also see videos of people who entered the contest in past years. Click on Contests on the top menu bar. When you go to the contest page, click on Past Year's Results at the bottom of the page.
- List your steps, and sketch out the design. What supplies will you need as you build your Rube Goldberg Machine?
- Develop your supply list, and scrounge for recycle materials.
- Once you have all your planning completed, you are ready to apply your design!

APPLY:

- Work through the engineering design process. It is okay to "work the problem" until you find a great solution.
- Set up your Rube Goldberg Machine, and test it.
- If any step didn't go as planned, discuss how you can redesign that section so it will function, and move the machine to the next step.
- What changes can you make to improve it?
- Test it several times.
- Videotape your Machine in action!



Supplemental Information

Rube Goldberg Machine Contest

If this issue of the 4-H STEM Activity galvanized (excite someone, typically into taking action) your interest, I have great news!

Rube Goldberg has an annual competition, and registration opens in September!

If you are interested, please let Dr. Barbara Shaw (barbara.shaw@colostate.edu) know that you want to participate in the 2018-19 Rube Goldberg Machine Contest.

There are two kinds of competitions:

- For the online competition, you design and build your machine, videotape it, and send your tape to the judges.
- For the live competition, you design and build your machine, transport it and you to the judges.

In the meantime, check these out:

- https://www.rubegoldberg.com/contest/
  - Click on one of the competitions. That will open another page with all the entries. They are identified as 1st, 2nd, 3rd, and People's Choice. The other entries are also great.
- http://coolmaterial.com/roundup/rube-goldberg-machines/ (Page turner is perfect for someone who isn't a morning person!)
- https://www.youtube.com/watch?v=7UdzAaw-H0o (America's Got Talent—Wow!)
- https://www.youtube.com/watch?v=QmOxqhEuBUM (especially for photographers!)
- https://www.youtube.com/watch?v=23Hzq8BG2YE (10 Rube Goldberg Machines in the movies)

Enjoy!