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Newton's Cradle

Demonstrating Newton's Laws On a Shoestring Budget

A Making Physics Fun Lab

By Brad Fulton
Educator of the Year, 2005
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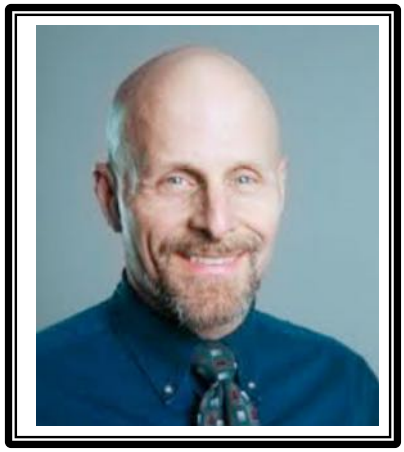
Brad Fulton

Educator of the Year



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- ♦ Consultant
- ♦ Educator
- ♦ Author
- ♦ Keynote presenter
- ♦ Teacher trainer
- ♦ Conference speaker

Known throughout the country for motivating and engaging teachers and students, Brad has co-authored over a dozen books that provide easy-to-teach yet mathematically rich activities for busy teachers while teaching full time for over 30 years. In addition, he has co-authored over 40 teacher training manuals full of activities and ideas that help teachers who believe mathematics must be both meaningful and powerful.

Seminar leader and trainer of mathematics teachers

- ♦ 2005 California League of Middle Schools Educator of the Year
- ♦ California Math Council and NCTM national featured presenter
- ♦ Lead trainer for summer teacher training institutes
- ♦ Trainer/consultant for district, county, regional, and national workshops

Author and co-author of mathematics curriculum

- ♦ Simply Great Math Activities series: six books covering all major strands
- ♦ Angle On Geometry Program: over 400 pages of research-based geometry instruction
- ♦ Math Discoveries series: bringing math alive for students in middle schools
- ♦ Teacher training seminar materials handbooks for elementary, middle, and secondary school

Available for workshops, keynote addresses, and conferences

All workshops provide participants with complete, ready-to-use activities that require minimal preparation and give clear and specific directions. Participants also receive journal prompts, homework suggestions, and ideas for extensions and assessment.

Brad's math activities are the best I've seen in 38 years of teaching!
Wayne Dequer, 7th grade math teacher, Arcadia, CA

"I can't begin to tell you how much you have inspired me!"
Sue Bonesteel, Math Dept. Chair, Phoenix, AZ

"Your entire audience was fully involved in math!! When they chatted, they chatted math. Real thinking!"
Brenda McGaffigan, principal, Santa Ana, CA

"Absolutely engaging. I can teach algebra to second graders!"
Lisa Fellers, teacher

References available upon request

Like my activities? How about giving me a favorable rating on the Teachers Pay Teachers website? Four stars would be much appreciated and would help me sleep better at night.

Like me even more? Then please don't make copies for your colleagues. I know it's tempting when they say, "Wow! Groovy activity! Can I have a copy?" But this is how I make my money, and why are they still saying "groovy" anyway?

If we make copies for our friends, can we honestly tell our students not to copy or take things that don't belong to them? (Ouch!)

Half priced site licensed copies are available on the TPT website. Please encourage them to take advantage of this affordable option. Okay?

Thanks and happy teaching,

Brad

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Great DVD presentations offer quality mathematics staff development at a fraction of the cost!

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- **Ongoing because** when you hire new staff, simply hit "play" and the training begins. There's no need to bring back the consultant.

Newton's Cradle

Demonstrating Newton's Laws of Motion on a Shoestring Budget

Overview:

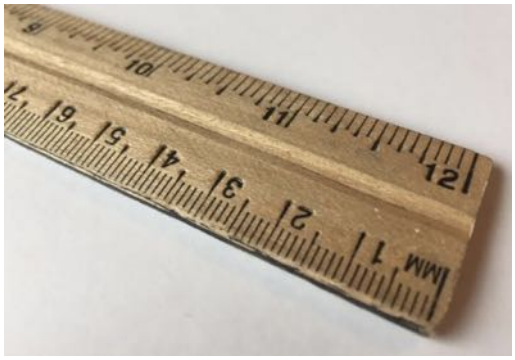
My students love to play with the Newton's cradle I have in my class. Five steel pendulums hang from nylon threads on a steel frame. By dropping one ball, the corresponding ball moves on the other side and then returns giving a visual demonstration of Newton's three laws of motion. The problem is that my 32 students can't play with one cradle. In this "STEM on a Shoestring" activity, students will make their own inexpensive models to demonstrate Newton's Laws. This handout contains many options for customizing the cradles to make them more versatile tools along with full illustrations and instructions plus two student worksheets and answer keys. Technology applications are also included.

Required Materials:

- ☒ Rulers or cardstock
- ☒ Marbles

Procedure:

1. You will need to obtain wooden rulers that have a groove down the center as shown. Avoid purchasing those that have holes drilled in them for binder rings as this will affect the motion of the marbles. If you cannot find the rulers, you can have students make paper channels out of cardstock. A master and instructions are provided for making these. These will be easier for younger students to work with as they provide a more secure channel for the marble than the narrow groove on the wooden rulers. However, I have found that the results are not as reliable with the paper channels. This might be a good issue to explore. You could have students experiment with both models and explain the advantages and disadvantages of each. I suspect the paper channels produce more friction on the marbles, and this may be what affects the outcome.



Clever tip!

My students' desks have a pencil tray that works great for this activity. We don't need rulers or paper channels. We just have to pick up lots of marbles off the floor!

2. Give each pair of students five marbles and one ruler. If you wish to have them complete the Newton's Cradle worksheet, pass that out also.
3. Have them set up four marbles near the center of the ruler as shown. They will roll a fifth marble along the track to hit the four. Ask them to write a hypothesis telling what they think will happen. Most students predict that the four marbles will move a

little bit. They reason that the four marbles will each receive 25% of the force of the rolling marble. Ask them to share their hypothesis.

4. Next let them test their hypothesis. When the one marble rolls in from the right it will come to an immediate rest alongside the set and the leftmost marble will roll away.

5. They should record their result on their lab sheet.
6. Next have them try rolling two marbles in from the side. Most students will want to test it first, but have them write their hypothesis before they do so. To ensure that they are writing the hypothesis, I ask a student to read aloud the hypothesis of their lab partner. This helps them attend to the process.

7. Then they can test their hypothesis. Two corresponding marbles roll away from the set.

8. As they move on to create other tests, their hypotheses will become more accurate. Have them consider what will happen if three marbles are rolled in from the side. It turns out that three roll away. That means that one of the marbles that rolled in is now also rolling out.

Notice the transfer of the blue marble

9. You can have them test four marbles rolling in against one.
10. Unlike a purchased Newton's Cradle that comes with five pendulums, you can add more marbles to your homemade channel. Here is a picture of two marbles ready to roll against a set of five.

11. Allow students to create their own tests. What might happen if you roll a large marble (called a "boulder") against a row of smaller marbles (called "shooters")? Depending on the setup, one of two results will occur. Typically, more than one small marble moves away as the force of the larger marble is distributed among them. However, sometimes it may occur that only one marble moves away, but it does so at a greater speed than the incoming large marble. This would be similar to an accident involving a slow-moving truck and a car. The car will absorb the force of the truck resulting in great damage, while the truck absorbs the smaller force of the car.

12. What might happen if you rolled a marble in from the left as you simultaneously rolled in a corresponding marble from the right?

13. **Newton's 1st Law of Motion** states that an object at rest remains at rest unless acted upon by an unbalanced force, and an object in motion remains in motion with the same speed and direction unless acted upon by an unbalanced force. Simply stated, resting things keep resting and moving things keep moving. This is demonstrated in this activity. The four marbles rest in the center of the ruler. Once the new marble (an unbalanced force) hits them, the force is transferred to the second marble, then the 3rd, then the 4th, until it finally is transferred to the final marble. This marble will then roll away. It would continue to roll forever were it not for friction (another unbalanced force) that eventually stops the motion of the last marble. Students may notice that the marbles roll better on the wooden track as it provides less friction.

    This also explains why a spacecraft requires a rocket engine. As the force of the exhaust exits the nozzle, there is an equal force that propels the the craft in the opposite direction. Since there is essentially no friction in space, the spacecraft can move indefinitely even when it runs out of fuel!

14. **Newton's 3rd Law of Motion** states that for every action, there is an equal and opposite reaction. This is clearly demonstrated in this activity when students notice that the number of entering marbles exactly matches the number of exiting marbles.

15. **Newton's 2nd Law of Motion** states that acceleration results when a force acts upon a mass. The greater the mass, the more force is needed to move it. Again, this is essentially simple; it means heavy objects are harder to move. This was demonstrated when the large marble was rolled against the set of four smaller ones. Students see that more force results from the impact because more than one marble moves.

Newton's Cradle Name_____

Lab Sheet Date_____ Class_____

1. Place four marbles near the center of your channel so they are touching edges. You will roll a fifth marble against them. What do you think will happen?

   Hypothesis: _____

   Result: _____

2. Now set up three adjacent marbles near the center of your ruler. And roll two against them.

   Hypothesis: _____

   Result: _____

3. Now you will set up two near the center and roll in three.

   Hypothesis: _____

   Result: _____

4. Now set up one marble near the center and roll in four.

   Hypothesis: _____

   Result: _____

5. Write a summary of what you have learned about how incoming forces and outgoing forces are related.

   _____

   _____

   _____

6. Design an experiment of your own. Describe it below. Then write your hypothesis and explain the result.

_____

_____

Hypothesis: _____

Result: _____

7. Look up Newton's 3rd Law of Motion and summarize it here. Then explain how it is illustrated in this activity.

_____

_____

_____

_____

_____

8. What is Newton's 1st Law of Motion? How is it evident in this lab?

_____

_____

_____

_____

_____

9. What is Newton's 2nd Law of Motion? Can it be demonstrated here?

_____

_____

_____

_____

_____

Answer Key:

1. One marble rolls away when one enters from the other side.
2. Two marbles roll away.
3. Three marbles roll away. The last of these is the first marble that entered.
4. Four marbles roll away: the resting one and three of the rolling ones.
5. For every marble that is rolled in, an equal number of marbles roll away. It is always balanced and is predictable.
6. Answers will vary.
7. **Newton's 3rd Law of Motion** states that for every action, there is an equal and opposite reaction. This is demonstrated by the fact that an equal number of marbles exit from the side opposite the entering marbles.
8. **Newton's 1st Law of Motion** states that objects at rest remain at rest and objects in motion remain in motion until another force acts upon them. The resting marbles don't move until they are struck by a moving marble. The exiting marble eventually comes to rest because of friction.
9. **Newton's 2nd Law of Motion** states that force = mass x acceleration. The fact that a larger marble causes more than one marble to exit demonstrates that the mass of the larger marble had a greater force propelling it. This greater force is transferred into the marbles with less mass.

Tech Tip:

A great follow-up can be found under the "Visual Physics" tab at FearofPhysics.com:

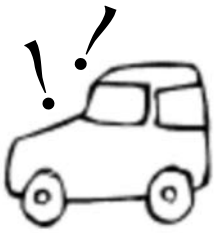
http://fearofphysics.com/Collide/collide.html.

Here students can use technology to perform a simulation of collisions. The following pages provide a lab sheet and answer key for this site.

COLLISION COURSE

Name_____

Date_____ Class_____



Go to: **www.fearofphysics.com**. Select "**visual physics**," then select "**collisions**." Use this site to answer these questions.

1. According to the introduction, what two factors determine what happens in a collision?

_____

Design the following collisions. Record the results in miles per hour. **Keep in mind that if the question asks about *velocity* the answer may be either positive or negative.**

- An SUV traveling at 10 mph and an SUV traveling at 10 mph.

  2. At what velocity does the car on the left approach the collision? _____

  3. At what velocity does the car on the right approach the collision? _____

- Now collide the left SUV at 10 mph and the right one at 30 mph.

  4. At what velocity does the car on the right approach the collision? _____

  5. At what velocity does the car on the left exit? _____

  6. What does this tell you about the forces? _____

- Next collide the left SUV at 10 mph and the right motorcycle at 50 mph.

  7. At what velocity does the car on the **left approach** the collision?_____

  8. At what velocity does the cycle on the **right exit** the collision? _____

  9. What accounts for this extra velocity in the motorcycle?

_____

- Next collide the SUV at 10 mph and the motorcycle at 90 mph.

10. At what velocity does the cycle **approach** the collision? _____

11. At what velocity does the cycle **exit** the collision? _____

12. Study the other numbers. Where does this missing force go?

_____

Fill in this chart for the collision. When entering data, enter **speed**, not velocity. That means that we **ignore the negative signs**.

	Entrance speed	Exit Speed
13. SUV	_____	_____
14. Motorcycle	_____	_____
15. TOTALS	_____	_____

16. What do you notice about the totals? _____

17. What does this tell you about the forces in a collision?

_____

- What is different about the **exit speed of the SUV** in these collisions:

A. The red truck at 10 mph and the SUV at 30 mph

B. The red truck at 30 mph and the SUV at 10 mph

18. _____

19. Which of the two collisions above (A or B) would cause the SUV to sustain the most damage? How can you tell?

_____

_____

_____

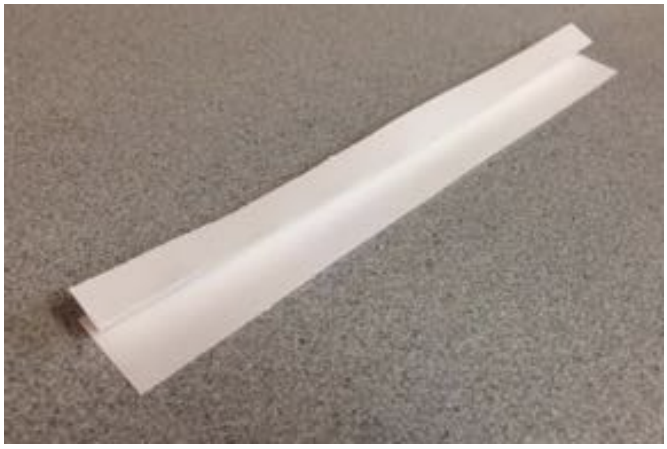
Answer Key: There are 19 questions in the lab sheet. If you wish to make grading easier, you can assign a two-point value to the final question.

1. The two factors that determine what occurs in a collision are the masses and speeds of the objects.
2. 10 mph
3. -10 mph
4. 10 mph
5. -30 mph
6. The force transfers from one vehicle to the other.
7. 10 mph
8. -56.70 mph
9. The mass of the SUV in addition to its speed produces a force on the motorcycle.
10. -90 mph
11. 87.84 mph
12. Some of the force of the motorcycle transferred to the SUV because of its speed.
13. 10 mph 12.16 mph
14. 90 mph 87.84 mph
15. 100 mph 100 mph
16. They are equal
17. All forces must be accounted for.
18. The SUV exits at 41.47 mph in the first collision but at 61.47 mph in the second.
19. The higher exit speed of the SUV in the second (B) collision suggests that it would cause more force to enter the SUV and thus it would sustain more damage.

Here are instructions for folding a paper channel from cardstock. A copy master is included. Cut the master along the solid lines and accordion fold it along the dotted lines.

Cut cardstock 11” by 2”.

Fold in half lengthwise.



Fold up one edge to the center.

Fold other edge to center also.

Spread out the folds of the finished channel.

The finished channel in action.

If you liked this activity, you might also like some of the other lessons available in my TeachersPayTeachers store. Simply search for "Brad Fulton".

You can also find many free and inexpensive resources on my personal website, www.tttpress.com. **Be sure to subscribe to receive monthly newsletters, blogs, and FREE activities.**

Similar ***S.T.E.M. ON A SHOESTRING*** activities include:

- *Slime Time* – A gooey lab involving Non-Newtonian fluids. Get the PowerPoint too!
- *Ramp Races* – An engaging and exciting way to teach students the principles of physics: forces, motion, speed, friction, and more!
- *Invisible Ink Lab* – Make hidden messages appear using the principles of chemistry and simple kitchen ingredients
- *Milk Lab* – Watch polar and non-polar molecules interact in this rainbow-hued lab. PowerPoint presentation available too!

Feel free to contact me if you have questions or comments or would like to discuss a staff development training or keynote address at your site.

Happy teaching,

Brad