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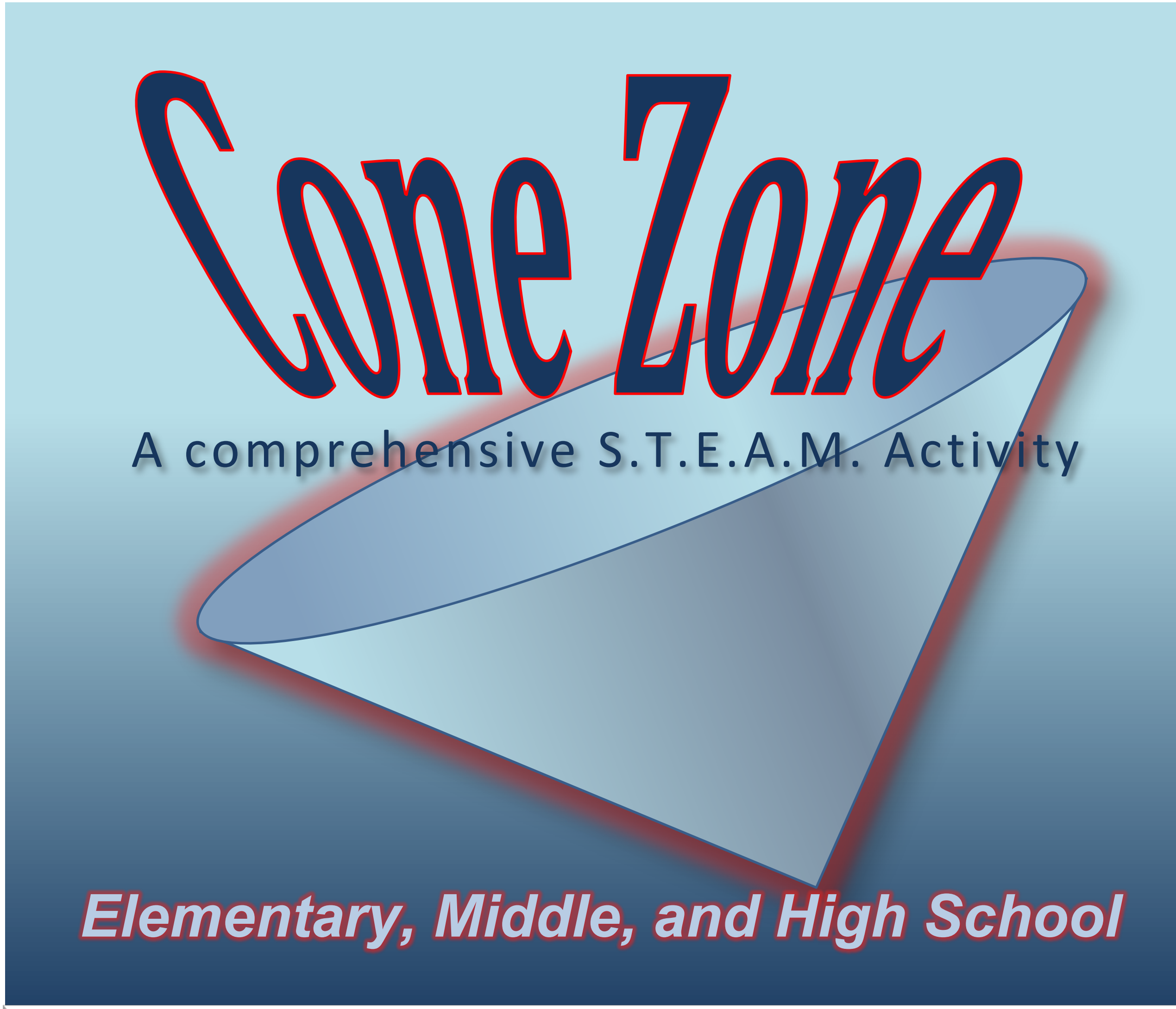

By Brad Fulton
Educator of the Year, 2005
brad@tttpress.com www.tttpress.com
530-547-4687
P.O. Box 233, Millville, CA 96062

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Brad Fulton

E d u c a t o r o f t h e Y e a r

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

PO Box 233, Millville, CA 96062
(530) 547-4687
b r a d @ t t t p r e s s . c o m

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

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!)

Discounted 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

OVERVIEW

Materials:

- [x] Cone template
- [x] Timers

Optional:

- [ ] Access to spreadsheet software

Cone Zone

Students will design a cone-shaped descent chute for a planetary landing craft to optimize stability and minimize speed in this engaging lesson. This activity lends itself to student scientists of many ages. Young learners will benefit from simply creating the cones and testing their effectiveness. Older students can use spreadsheets that they create to analyze the data on a much more sophisticated level.

Vocabulary: cone, volume, lateral area, descent

PROCEDURE

Skills:

- Volume of cones
- Lateral and surface area of cones
- Measuring time
- Rounding decimals
- Gathering data
- Analyzing data
- Interpreting data
- Using spreadsheets

1. Begin by explaining to your students that they have been asked to help design a descent system for a robotic explorer on another planet. Their goal is to land the craft safely and accurately of course.

2. Show them a circle of paper and drop it from a height of two meters. Ask them what they notice. They will likely note that it drifts and flips as it slowly descends. Ask them how that would work for a landing craft. They should realize that although it descended slowly, it was not stable, and the craft likely would not survive the landing.

3. Now show them a circle that has been formed into a cone. This cone should have a 60° angle removed. To make the rest of the lesson easier, you may wish to have them watch how you build this cone.

4. Drop it from a height of two meters with the vertex of the cone pointed toward the floor.

5. Ask them what they noticed about the descent. They will likely notice that it descended with much greater stability and accuracy. However, they may not notice that its descent rate was not the same; it was likely a bit faster.

6. You may wish to drop both again and time their descents.

7. Now explain to the students how they will conduct their investigation. They will be working as an engineering team. Each group of students will design and test specific cones by removing an assigned number of degrees from the full circle.

8. To build a cone, first cut out the circle. Then cut along the bold arrow at 0°. Now move the arrow to the desired number of degrees and glue or tape the overlapping parts to create the cone. Allow the glue to dry.

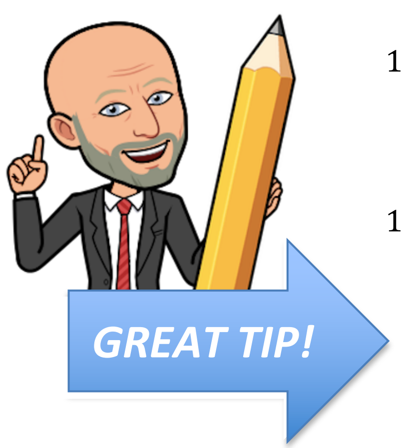
9. Now assign different cones to different groups. Start with a cone in which 10° has been removed. Then increase each group by ten more degrees. In my class, there are eight groups of students. Thus, we would start with cones corresponding to 10°, 20°, 30°, 40°, 50°, 60°, 70°, and 80° sectors removed.

10. Then have them create a second set beginning with 90° removed. Continue this way until you have covered enough angles to suit your needs.

11. To test them, have them drop them from a height of two meters. If you have younger students, you may have to do this for them. You will also need to place a marker on the floor as a target if you are testing accuracy. A simple "x" made from tape or a sticky dot will suffice.

12. Have at least two students time them. If their times do not match fairly well, have them try again. The time is recorded on their Cone Zone lab sheet.

13. If you are using the Cone Zone 3 lab sheet, have them also measure distance away from the target in centimeters. This should also be recorded on the lab sheet.



14. For greater accuracy, have the students take multiple drops of their cone and average them. Alternately, you can have each member of the team create their own cone. If you have four students per team, they will be testing four identical cones and averaging the data. They can also graph of their data. This can be done by hand or by using online software such as Desmos (www.desmos.com) or Google Sheets.

Volume – the space inside a three-dimensional shape. In this case, the volume of the cone is the amount of air being trapped inside during the descent. The formula for the volume of a cone is:

$$V = \frac{1}{3}\pi r^2 h$$

Students will need to set their cones on their tables and measure the radius and height in centimeters. The volume will then be in cubic centimeters

Lateral Area – the amount of surface of the sides of the cone *but not including the base*. Since the cone does not have a base in this case, we don't include it. The formula for lateral area is:

$$A_L = \pi r \sqrt{h^2 + r^2}$$

However, it is much easier to calculate the lateral area *before* assembling the cone. Then we see that the lateral area is some fraction of the original circle. The formula would be:

$$A_L = \pi r^2 \left(\frac{360 - n}{360}\right)$$

where n is the degree measure of the cut.

Online calculators for these measurements can be found.

15. Test the remainder of the cones in a similar way.

16. Now they will need to aggregate their data. Have each team report their data to the entire class so that everyone can fill in their charts.

17. More advanced students will use Cone Zone 4 data chart. They will need to include the *volume* of their cone and the *lateral area*. This is explained on the left.

18. If you wish, instructions are provided for students to create a spreadsheet that will do their calculations for them. The spreadsheet corresponding to Cone Zone 4 is challenging and will likely frustrate any student who doesn't attend to detail on every step. You will find that any one of the online calculators will be more efficient. Simply search for "volume of a cone calculator." The spreadsheet instructions are provided for the teacher who wants their students to learn this skill.

Lab Sheet Options

Four different lab sheets and three spreadsheet options are provided to allow you to customize this activity to your students:

Cone Zone 1: This is the simplest of the four lab sheets. This will also be the lab that will take the least class time. Students simply time the descent rates. Spreadsheet instructions are provided for this if you wish to use them.

Cone Zone 2: In this version, students time the descent rates in seconds. Then they divide that into the number 2. That is, they take 2÷*s*, where *s* is the descent rate in seconds. This gives the average speed in meters per second, or mps, which is also abbreviated as m/s. Spreadsheet instructions are also provided for this version.

Cone Zone 3: Now students look at two variables: descent time and accuracy. This requires less mathematical rigor but more critical thinking. It may be that one angle provides the best descent rate while another provides more accuracy.

Cone Zone 4: The most sophisticated version of the lab requires students to compare descent rates and average speeds while also calculating the lateral area of the cone and the volume of the air it contains.

There are other ways to extend this lesson into an in-depth investigation. Students may want to try some of these experiments or do research to find the answers to the questions.

- What effect does scaling have on the results of the experiment? If you *double* the diameter of the circle, does that affect the descent time?
- Does the type of paper matter in this activity? If you use card stock instead of printer paper, does the descent time or accuracy change?
- Does the shape of the chute matter? If you use a square instead of a circle, is it more or less stable? What happens to the descent time?
- What happens of you drop the cones from a greater height?
- How does a parachute change the *terminal velocity* of a falling object? What is the terminal velocity on earth? On Mars? What is the terminal velocity of a typical parachute?
- What are the *balanced* and *unbalanced* forces in this lab?

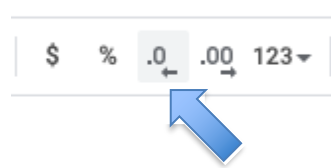
Cone Zone 1 Spreadsheet Instructions

1. Open up a Google Sheet
2. In cell A1, type: **Degrees of cut**
3. In cell B1, type: **Descent time**
4. In cell A2, type: **10**
5. In cell A3, type: **=A2+10** (The equal sign tells the spreadsheet to do some math calculation for you. You will see that cell A3 now displays 20 even though you didn't type that. It went to cell A2, found a 10, and added 10 to it as you commanded.)
6. Highlight cell A3 through cell A21. Select "Fill Down" from the edit menu. Alternately, most software allows you to do this with a Ctrl+D command.
7. Input your descent time in seconds in column B.

If you wish, you can graph the data. Highlight cells A2 through B21. Go to "Insert", then select "Chart". It will create a graph for you. You can change the type and format of the graph if you wish.

Cone Zone 2 Spreadsheet Instructions

1. Open up a Google Sheet
2. In cell A1, type: **Degrees of cut**
3. In cell B1, type: **Descent time**
4. In cell C1, type: **Speed (m/s)**
5. In cell A2, type: **10**
6. In cell A3, type: **=A2+10** (The equal sign tells the spreadsheet to do some math calculation for you. You will see that cell A3 now displays 20 even though you didn't type that. It went to cell A2, found a 10, and added 10 to it as you commanded.)
7. Highlight cell A3 through cell A21. Select "Fill Down" from the edit menu. Alternately, most software allows you to do this with a Ctrl+D command.
8. Enter your descent times in column B.
9. In cell C2, type: **=2/B2** This will calculate your speed in meters (m) per second (s).
10. Highlight cells C2 through C21 and "Fill Down". Notice that the speeds are calculated automatically by the spreadsheet.
11. You may find some lengthy decimals when this happens. To round them off, highlight cells C2 through C21 and click the "Decrease decimal places icon" at the top.



If you wish, you can graph the data. Highlight cells A2 through B21. Go to "Insert", then select "Chart". It will create a graph for you. You can change the type and format of the graph if you wish.

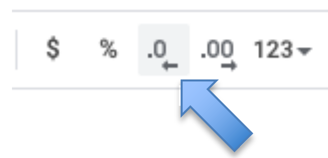
Cone Zone 3 Spreadsheet Instructions

1. Open up a Google Sheet
2. In cell A1, type: **Degrees of cut**
3. In cell B1, type: **Descent time**
4. In cell C1, type: **Distance from target**
5. In cell A2, type: **10**
6. In cell A3, type: **=A2+10** (The equal sign tells the spreadsheet to do some math calculation for you. You will see that cell A3 now displays 20 even though you didn't type that. It went to cell A2, found a 10, and added 10 to it as you commanded.)
7. Highlight cell A3 through cell A21. Select "Fill Down" from the edit menu. Alternately, most software allows you to do this with a Ctrl+D command.
8. Input your descent time in seconds in column B.
9. Input your distances from the target in column C.

If you wish, you can graph the data. Highlight ca column or columns. Go to "Insert", then select "Chart". It will create a graph for you. You can change the type and format of the graph if you wish.

Cone Zone 4 Spreadsheet Instructions

1. Open up a Google Sheet
2. In cell A1, type: **Radius:**
3. In cell B2, enter the radius of your cone template in centimeters
4. In cell A2, type: **Degrees of cut**
5. In cell B2, type: **Descent time**
6. In cell C2, type: **Speed (m/s)**
7. In cell D2, type: **Volume of cone**
8. In cell E2, type: **Lateral area**
9. In cell A3, type: **10**
10. In cell A4, type: **=A3+10** (The equal sign tells the spreadsheet to do some math calculation for you. You will see that cell A4 now displays 20 even though you didn't type that. It went to cell A3, found a 10, and added 10 to it as you commanded.)
11. Highlight cell A4 through cell A22. Select "Fill Down" from the edit menu. Alternately, most software allows you to do this with a Ctrl+D command.
12. Input your descent times in column B.
13. In cell C3, type **=2/B3** This will calculate the speed in meters (2) per second.
14. Highlight cells C3 through C22 and fill down.
15. You may find some lengthy decimals when this happens. To round them off, highlight cells C2 through C21 and click the "Decrease decimal places icon" at the top.



16. In cell D3, type: **=(1/3)*3.14*(((360-A3)/360)*B$1)^2*((B$1^2-(((360-A3)/360)*B$1)^2))^.5**
17. Now raise your right hand, reach across your left shoulder, and give yourself a pat on the back for typing that equation!
18. Highlight cells D3 through D22 and fill down.
19. In cell E3, type: **=(360-A3)/360*3.14*B$1^2**
20. Make sure you get all those parentheses correct, and don't forget the equal sign. What this formula does is find the area of your whole circle and then the fraction of it that remains when the sector is removed.
21. Highlight cells E3 through E22 and fill down.

If you wish, you can graph the data. Highlight a column or columns. Go to "Insert", then select "Chart". It will create a graph for you. You can change the type and format of the graph if you wish.

Cone Zone 1

Name________________________________

Date____________________ Class________

Fill out the data table using the data collected by your team and the other teams.

Degrees of cut	Descent time
10°	
20°	
30°	
40°	
50°	
60°	
70°	
80°	
90°	
100°	
110°	
120°	
130°	
140°	
150°	
160°	
170°	
180°	
190°	
200°	

Cone Zone 2

Name______________________________

Date___________________ Class_______

Fill out the data table using the data collected by your team and the other teams.

Degrees of cut	Descent time	Speed (mps)
10°		
20°		
30°		
40°		
50°		
60°		
70°		
80°		
90°		
100°		
110°		
120°		
130°		
140°		
150°		
160°		
170°		
180°		
190°		
200°		

Cone Zone 3

Name________________________________

Date____________________ Class_______

Fill out the data table using the data collected by your team and the other teams.

Degrees of cut	Descent time	Distance from target
10°		
20°		
30°		
40°		
50°		
60°		
70°		
80°		
90°		
100°		
110°		
120°		
130°		
140°		
150°		
160°		
170°		
180°		
190°		
200°		

Cone Zone 4

Name______________________________

Date____________________ Class_______

Fill out the data table using the data collected by your team and the other teams.

Degrees of cut	Descent time	Speed (mps)	Volume of cone	Lateral area
10°				
20°				
30°				
40°				
50°				
60°				
70°				
80°				
90°				
100°				
110°				
120°				
130°				
140°				
150°				
160°				
170°				
180°				
190°				
200°				

Cone Zone

Name_______________________________

Date__________________ Class________

Report summary

What angle should be removed to optimize the descent rate? Write a summary to the aerospace company that hired you explaining your recommendation of the ideal cone that should be built. In your summary, tell the volume of air captured in the cone and the lateral area of the material used to build it. Include the formulas for your work so that they can verify your results. Also include a diagram of the cone on the back of this page giving the dimensions of your model (diameter, slant height, and height) in centimeters.

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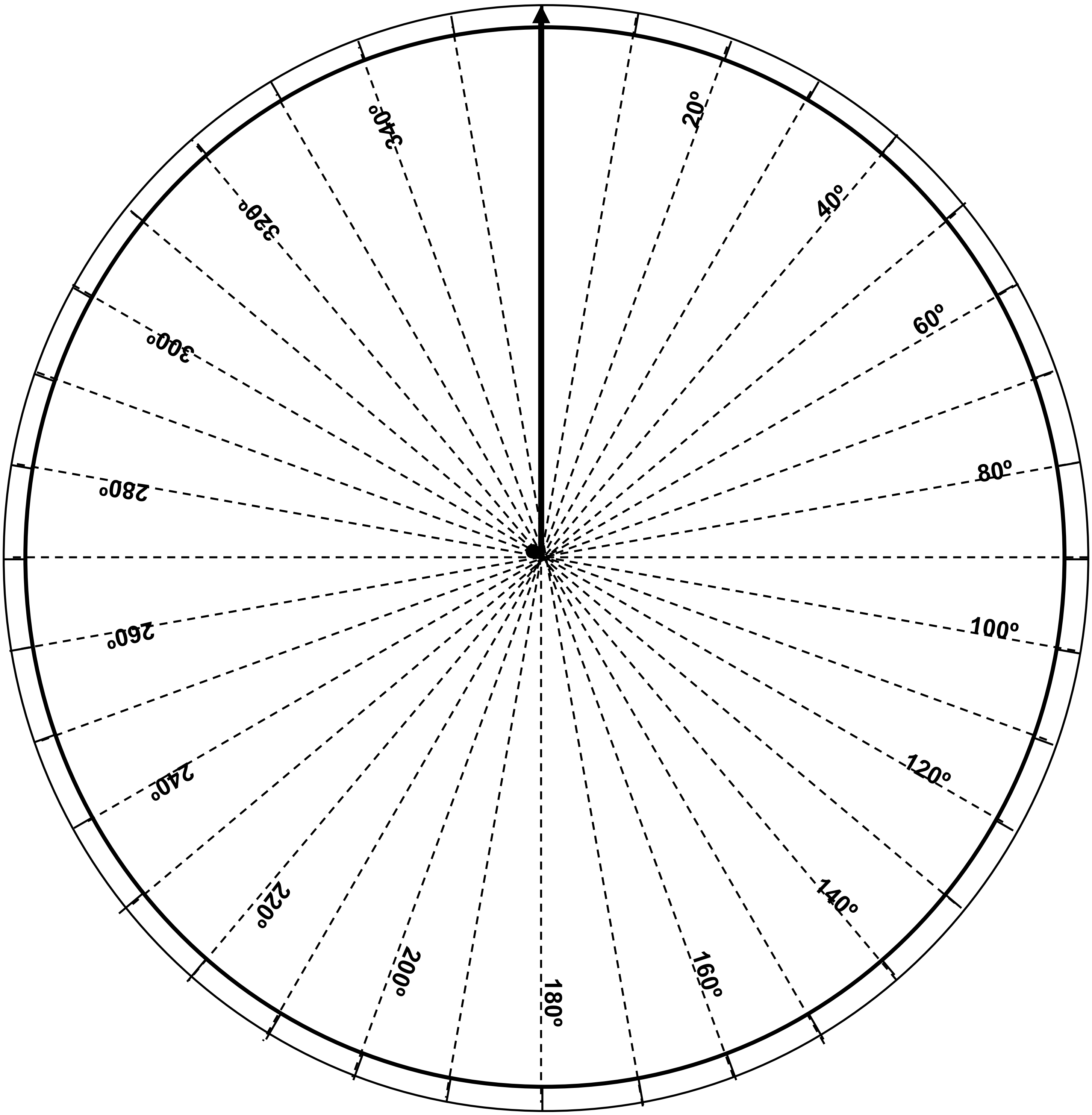
Cone template

1. Cut out the circle.
2. Cut along the arrow.
3. Line up the arrow with the desired angle and glue it to form the cone.



A complete S.T.E.A.M. lesson!

For the S.T.E.M. or S.T.E.A.M. teacher, this activity hits on all cylinders. Include whatever components you wish for a comprehensive and connected experience.

Science:

- Physics of gravity and drag
- Study of planetary exploration such as on Mars

Technology:

- Using online software for calculation and graphing
- Creating and using spreadsheets
- Researching planetary atmospheres and gravity online

Engineering:

- Creating cones to use as descent devices

Arts:

- Writing a summary report based on evidence
- Creating a diagram of a descent device

Math:

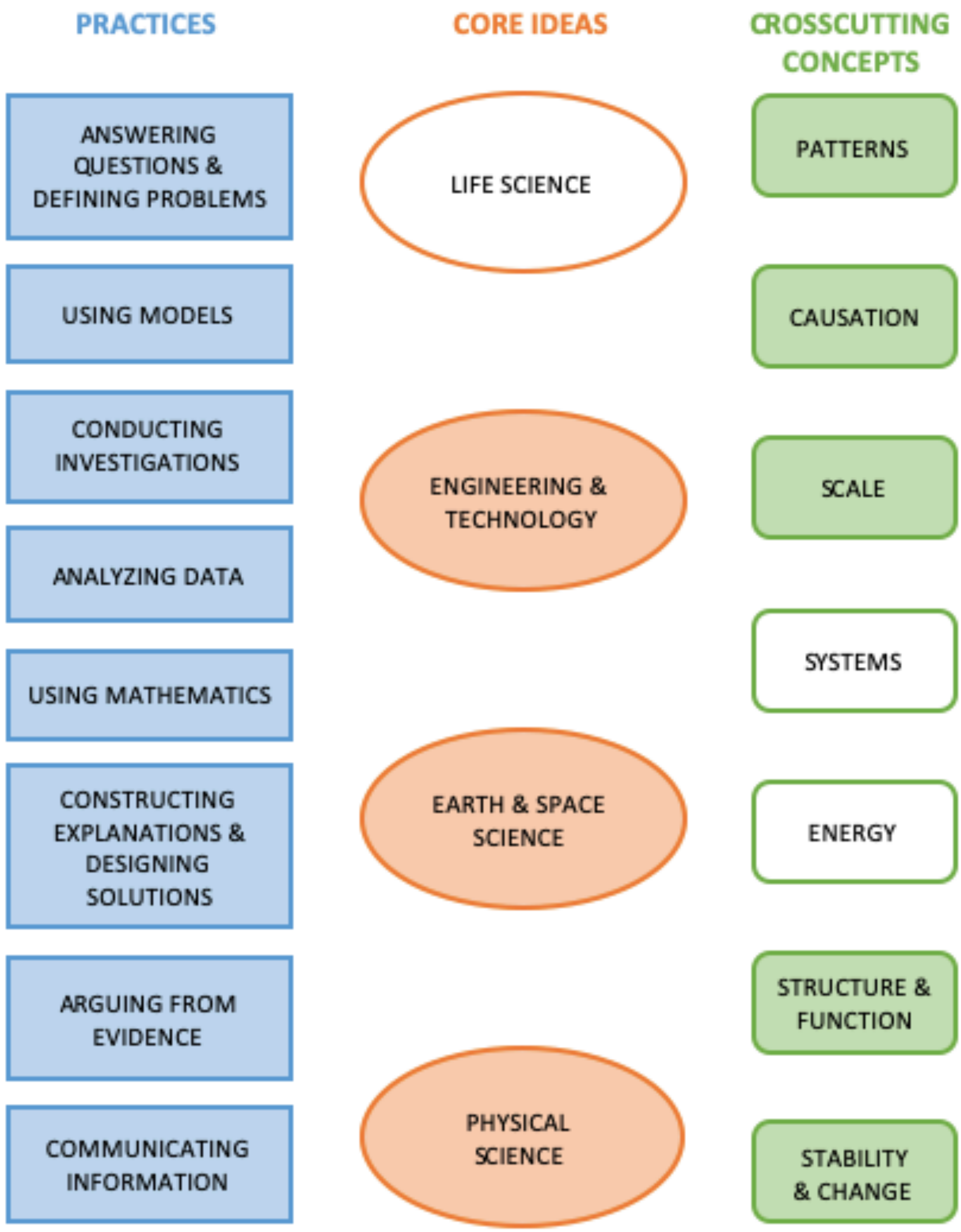
- Measure time of the descents
- Measure distances in centimeters
- Round decimals
- Find averages
- Graph data

The Common Core Connection

Fifth:
CCSS.MATH.CONTENT.5.NBT.A.3.B
Compare two decimals to thousandths based on meanings of the digits in each place, using >, =, and < symbols to record the results of comparisons.
CCSS.MATH.CONTENT.5.NBT.A.4
Use place value understanding to round decimals to any place.
CCSS.MATH.CONTENT.5.MD.B.2
Make a line plot to display a data set of measurements in fractions of a unit (1/2, 1/4, 1/8). Use operations on fractions for this grade to solve problems involving information presented in line plots. *For example, given different measurements of liquid in identical beakers, find the amount of liquid each beaker would contain if the total amount in all the beakers were redistributed equally*.

Sixth:
CCSS.MATH.CONTENT.6.SP.A.2
Understand that a set of data collected to answer a statistical question has a distribution which can be described by its center, spread, and overall shape.
CCSS.MATH.CONTENT.6.SP.A.3
Recognize that a measure of center for a numerical data set summarizes all of its values with a single number, while a measure of variation describes how its values vary with a single number.
CCSS.MATH.CONTENT.6.SP.B.4
Display numerical data in plots on a number line, including dot plots, histograms, and box plots.
CCSS.MATH.CONTENT.6.SP.B.5
Summarize numerical data sets in relation to their context, such as by:
CCSS.MATH.CONTENT.6.SP.B.5.A
Reporting the number of observations.
CCSS.MATH.CONTENT.6.SP.B.5.B
Describing the nature of the attribute under investigation, including how it was measured and its units of measurement.
CCSS.MATH.CONTENT.6.SP.B.5.C
Giving quantitative measures of center (median and/or mean) and variability (interquartile range and/or mean absolute deviation), as well as describing any overall pattern and any striking deviations from the overall pattern with reference to the context in which the data were gathered.
CCSS.MATH.CONTENT.6.SP.B.5.D
Relating the choice of measures of center and variability to the shape of the data distribution and the context in which the data were gathered.

Eighth
Solve real-world and mathematical problems involving volume of cylinders, cones, and spheres.
CCSS.MATH.CONTENT.8.G.C.9
Know the formulas for the volumes of cones, cylinders, and spheres and use them to solve real-world and mathematical problems.


PRACTICES
CORE IDEAS
CROSSCUTTING CONCEPTS
ANSWERING QUESTIONS & DEFINING PROBLEMS
USING MODELS
CONDUCTING INVESTIGATIONS
ANALYZING DATA
USING MATHEMATICS
CONSTRUCTING EXPLANATIONS & DESIGNING SOLUTIONS
ARGUING FROM EVIDENCE
COMMUNICATING INFORMATION
LIFE SCIENCE
ENGINEERING & TECHNOLOGY
EARTH & SPACE SCIENCE
PHYSICAL SCIENCE
PATTERNS
CAUSATION
SCALE
SYSTEMS
ENERGY
STRUCTURE & FUNCTION
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Similar ***S.T.E.M. ON A SHOESTRING*** activities include:

- *3-2-1 Launch: Designing Catapults* – This popular STEM lesson contains adaptations for primary though high school students.
- *Drop Zone: Parachute Lesson* – Another engaging lesson that is highly adaptable and contains all the elements of science, technology, engineering, and math.
- *Ramp Races* – An engaging and exciting way to teach students the principles of physics: forces, motion, speed, friction, and more!

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