Barbie® Doll Bungee Jumping
Graphing and Extrapolating Data

Objective
Students will work in teams, gather and graph data, and generate a manual fit line and an equation for their line. Students will practice making predictions from a linear equation. Through this activity, students will gain an appreciation for simulations and the beauty of mathematics in science.

Level
Middle Grades: Earth Science

Common Core Standards
TBD

Connections to AP*
AP Physics: I. Newtonian mechanics B. Newton's laws of motion 2. Dynamics of a single particle (second law) F. Oscillations and gravitation 1. Simple harmonic motion (dynamics and energy relationships)

**Advanced Placement and AP are registered trademarks of the College Entrance Examination Board. The College Board was not involved in the production of this product.*

Materials
For a class of 28 working in groups of four

280 rubber bands (each approximately 4 in. unstretched length)
graphing calculators or computer graphing software (optional)
balances
7 Barbie® dolls or other action figures
7 meter sticks
tape measure

T E A C H E R

Teacher Notes

The task of this activity is to determine the relationship between the number of rubber bands and the jump height that will result in a safe yet thrilling jump for Barbie®. The doll must be allowed to come as close to the floor as possible without sustaining any "injuries." You can ask students to bring in their own dolls or action figures. Each group works with just one doll.

Students should make at least three trials when dropping Barbie® from each height and then use the average. Instruct students to test-drop several times to practice taking readings. Students will need to plot their data and develop a mathematical equation to extrapolate and predict how many rubber bands will be required for their next jump. Refer to the Foundation Lesson "Graphing Skills" for assistance with graphing.

Consider dropping Barbie® from a balcony, stadium bleacher, gym bleacher, or band director's platform. Do not tell the students where the test jump will be made, only its height. You may want to vary the location from period to period to foil cheating attempts. This is especially important if you will be performing the jump on a subsequent day.

The athletic staff usually has a very long tape measure that will simplify the measuring task. If a long tape measure is not available, use a long string with a small amount of weight tied to the end. Lower the string to the ground until the weight just touches, mark the length on the string, and then use a meter stick to measure the string.

An extension of this activity would be to give students the heights in feet and inches so they must apply dimensional analysis to successfully convert the given height to meters. Refer students to the Foundation Lesson "Numbers in Science" for help with dimensional analysis.

Buy plenty of rubber bands. Two-pound boxes from an office supply store work well.

Be aware that after several uses the rubber bands will permanently deform or stretch, and this may affect the accuracy of the prediction. Let students discover and cope with this complication in any reasonable way. Some of them may consider pre-stretching the rubber bands, or replacing the old rubber bands with new ones frequently, or replacing the old rubber bands for the final test jump only.

Although rubber bands are not truly elastic and do not have a definite spring constant or "stretch constant" as used in this lab, this activity serves a useful purpose in developing data gathering, graphing, inquiry, and data analysis skills.

Teacher Notes (continued)

The stretch of a rubber band is dramatically different from the stretch of a spring. A spring is *elastic*—it obeys Hooke's law, and it stretches and un-stretches the same way. Instead, a rubber band shows *hysteresis*—it un-stretches very differently than it stretches, and it certainly does not follow Hooke's law (see Figure A). Rubber bands are not elastic.

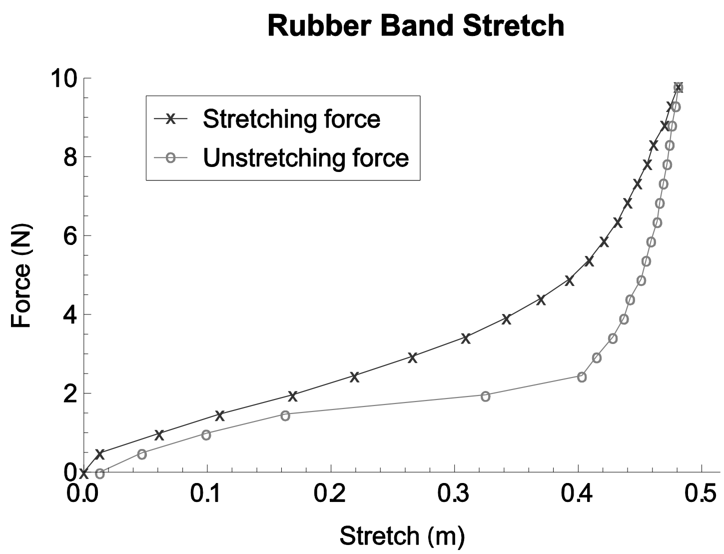


Figure A. Rubber band stretch

For further information about the behavior of rubber bands, there is an extensive lesson in the physics activities called "Hysteresis" that studies this behavior of materials and includes a change in temperature as they change shape.

Acknowledgements
All references to Barbie imply the Barbie® doll or action figure. BARBIE is a registered trademark used with permission from Mattel, Inc. © 2008 Mattel, Inc. All Rights Reserved.

Answer Key

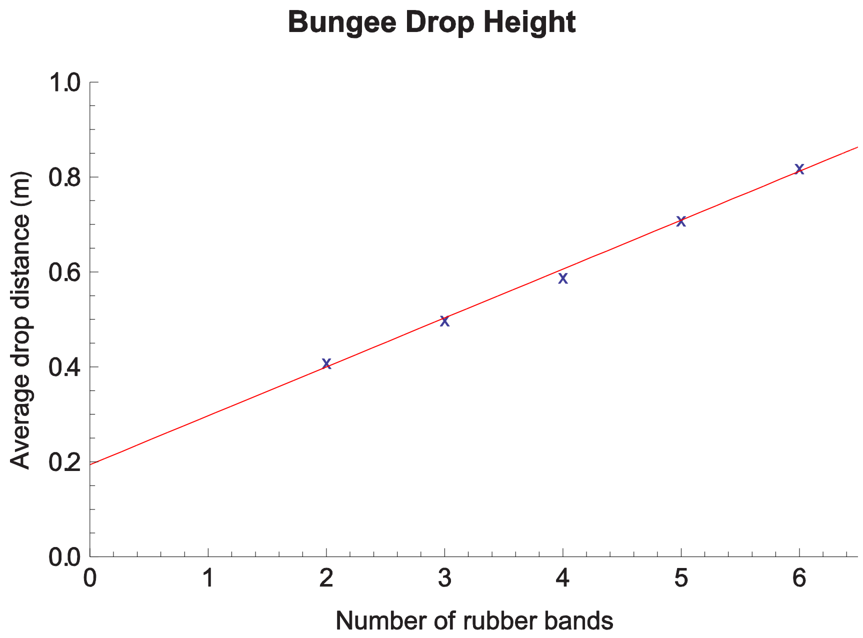
Data and Observations

Mass of the Barbie® Doll = 119 g

Data Table

Table A: Bungee Drop Height					
Number of Rubber Bands	**Initial Length of Bungee Cord (m)**	**Maximum Drop Distance (m)**			
		Trial 1	**Trial 2**	**Trial 3**	**Average**
2	0.13	0.41	0.40	0.42	0.41
3	0.19	0.51	0.50	0.50	0.50
4	0.27	0.57	0.60	0.60	0.59
5	0.34	0.70	0.71	0.71	0.71
6	0.42	0.81	0.82	0.83	0.82

Graph



T E A C H E R

Answer Key (continued)

Conclusion Questions

1. With a slope of 0.10 and a *y*-intercept of 0.19, the equation of the best fit line is

$$y = 0.10x + 0.19$$

2. A *y*-intercept of 0.19 means that with zero rubber bands attached to the doll, the drop height is 0.19 m. By converting this quantity to inches, this value can yield the approximate height of the doll:

$$19\text{ cm} \times \frac{1\text{ in.}}{2.54\text{ cm}} = 7.5\text{ in.}$$

3. First, convert the height to meters:

$$100.0\text{ ft} \times \frac{12\text{ in.}}{1\text{ ft}} \times \frac{2.54\text{ cm}}{1\text{ in.}} \times \frac{1\text{ m}}{100\text{ cm}} = 30.48\text{ m}$$

On the graph, the *y*-axis is the height in meters and the *x*-axis is the number of rubber bands used. Thus, the slope has units of *meters per band* (m/band). Because *y* will be equal to 30.48 m, we need to solve for *x*.

Use a graphing method or do the algebra, substituting the information from your graph into the equation:

$$y\text{ meters} = 0.10\frac{\text{meters}}{\text{band}}(x\text{ number of bands}) + 0.19\text{ meters}$$

$$30.48\text{ m} = 0.10\frac{\text{m}}{\text{band}}(x\text{ bands}) + 0.19\text{ m}$$

Solve for *x*:

$$\frac{30.48\text{ m} - 0.19\text{ m}}{0.10\text{ m/band}} = 302.9\text{, or about 302 rubber bands}$$

4. The amount of stretch is equal to the maximum drop distance minus the doll's height, and minus the initial length of the bungee cord.

$$\text{stretch factor} = \frac{\text{amount of stretch (m)}}{\text{mass of Barbie}^{®}\text{ (g)}} = \frac{0.59\text{ m} - 0.19\text{ m} - 0.27\text{ m}}{119\text{ g}} = 1.1 \times 10^{-3}\text{ m/g}$$

5. Barbie's® boyfriend is a different height and mass, so a bungee cord calculated for her specific height and mass would not be safe for anyone else to use. The cord may be stretched further than is safe, and her boyfriend may suffer serious injury.

6. The stretch factor will increase, as the doll's mass will be reported as too small. Her mass is in the denominator of the stretch factor calculation, so we will divide by a value that is too small and will make the reported factor too large.

T E A C H E R

Barbie® Doll Bungee Jumping
Graphing and Extrapolating Data

Team members have been hired to work for the Psycho Entertainment Company. This company provides rock climbing, sky diving, extreme skateboarding, and hang gliding adventures to the public. The current market research indicates that the company should add bungee jumping to its list of entertainment services.

As part of the preliminary research, the management assigned teams the task of working out the details of the jump that will ensure a safe yet thrilling experience. The company has several sites planned for bungee jumping and each site is at a different height.

Purpose
To ensure a safe and thrilling jump, you will determine the relationship between the jump height and the number of rubber bands used to make the bungee cord. You must allow your doll to come as close to the floor as possible without sustaining any "injuries" or "fatalities."

Materials
rubber bands, 7 to start
graphing calculator or computer graphing software (optional)
balance
Barbie® doll or other action figure
meter stick

Safety Alert!

- Use extreme caution during the "jumps."
- Wear safety goggles.

Procedure

1. Use one rubber band to secure the doll's ankles together and to serve as a point of attachment for the bungee cord. Use a small rubber band to tie back the doll's hair if it is not already in a ponytail.
2. Determine the mass of the doll on the balance. Record this value in your observations.
3. Construct a bungee cord composed of 2 rubber bands and attach it to the band on the doll's ankles. Barbie® will fall freely from a standing position, plunging head-first throughout this activity.
4. Measure the initial length of the two-band bungee (not including the doll's height) you constructed once it is attached to the doll's ankles. Test drop Barbie® several times to practice taking readings. Repeat this jump two more times, for a total of three trials.
5. Create a data table to record the trials, the length of the bungee cord, and the drop distance. Remember that you will be adding up to a total of 6 rubber bands and you will need to record an average value.
6. Add a rubber band to your attached bungee cord. Measure the new cord length, drop Barbie® three times using the new cord, and record the data.
7. Repeat Step 6 until you have a total of 6 rubber bands. Additional trials may be performed if time permits. You may have to devise a way to take measurements that are longer than 1.0 meter.
8. Calculate the averages and record them in your data table.
9. Use the space provided to construct a graph of the data. Use a straight edge to draw a line in such a way that an equal number of points lie above and below the line.
10. Develop an equation for this line in $y = mx + b$ format and record it. Remember that to calculate the slope of the line, use the equation

$$\text{slope} = \frac{\text{rise}}{\text{run}} = \frac{\Delta y}{\Delta x} = \frac{y_2 - y_1}{x_2 - x_1}$$

    The *y*-intercept (*b*) can be found by extending this line backward until it crosses the *y*-axis.

11. Use your equation to predict how many rubber bands will be needed for Barbie® to perform a safe yet thrilling jump for each location that your teacher specifies. Your teacher will set the boundaries for both the doll's safety and her "thrill factor."
12. Create a bungee cord based on the number of rubber bands you predicted in Step 11, and attach it to the doll. When directed by your teacher, proceed to the drop zone and test your prediction.

Data and Observations

Mass of the Barbie® Doll = ____________ g

Data Table

Graph

Conclusion Questions

1. Write the equation for the line you developed on your graph.

2. What is the significance of the *y*-intercept in your equation?

3. Use your equation to predict how many of your rubber bands would be needed to allow Barbie® a successful yet thrilling jump from a height of 100.0 feet. Show all calculations in the space provided.

Conclusion Questions (continued)

4. Calculate the factor coefficient for the trial that used 4 rubber bands by using the following formula:

$$\text{stretch factor} = \frac{\text{amount of stretch (m)}}{\text{mass of Barbie}^{®}\text{ (g)}}$$

5. Barbie's® boyfriend wants to bungee jump and have some fun, too. Barbie® loans her bungee cord to her boyfriend but warns that this may not be a safe plan. Why may it be a bad idea for someone else to use Barbie's® bungee cord?

6. A student measured the mass of Barbie® before attaching the first rubber band that secures the doll's ankles to the bungee cord. How will this error affect the calculated value of the stretch factor? Your answer should state clearly whether the stretch factor increases, decreases, or remains the same and must be justified mathematically.