Bungee-Jumping Egg

Introduction

Bungee jumping would not be as "safe" as it appears to be without relying on some basic physics principles, such as the conservation of energy and Hooke's law for springs. A safe bungee jump occurs when no one is injured. An exhilarating bungee jump is one in which no one is injured, the free fall lasts as long a time as possible, and the bungee jumper comes as close to the ground as possible without touching it. In this activity, the law of conservation of energy and Hooke's law will be used to build a safe *and* exhilarating model bungee jump of an egg!

Concepts

- Hooke's law for springs
- Acceleration of gravity
- Conservation of energy

Background

The law of conservation of energy states that energy can not be created or destroyed, only converted between one form and another. During a bungee jump, the stored, potential energy (PE) of the jumper on a tall platform ($PE = mgh$) is converted into kinetic energy (KE) during the fall ($KE = 1/2mv^2$). This kinetic energy is converted back into potential energy as the bungee cord (rubber band chain) stretches. At the bottom of the "ride," when the jumper momentarily stops, all the kinetic energy has been converted into spring potential energy—the energy stored in the stretched bungee cord ($PE_{spring} = 1/2kx^2$). An instant later, the bungee jumper is flung upward as the bungee cord relaxes, thereby converting the spring potential energy back into kinetic energy. An egg will simulate the bungee jumper in this experiment.

In order to determine the appropriate length of string needed to make the bungee cord long enough for a safe and exhilarating ride, five quantities are needed—(1) the total height of the jump that is desired, (2) the initial length of the unstretched rubber band chain, (3) the spring constant of the rubber band chain, (4) the mass of the egg, and (5) the length of the basket (see Figure 1). The total height of the jump (h) is the height above the ground at which the jump begins (PH) *minus* the separation distance between the egg and the ground at the bottom of the ride (Equation 1).

$$PH - d = h = SL + UL + BL + X \qquad \textit{Equation 1}$$

PH = Platform height above the floor

h = Total height of the jump

SL = String length

UL = Unstretched rubber band chain length

BL = Egg basket length

X = Stretch distance of rubber band chain during jump

d = Separation distance between egg and floor at the bottom of the ride (2 cm)

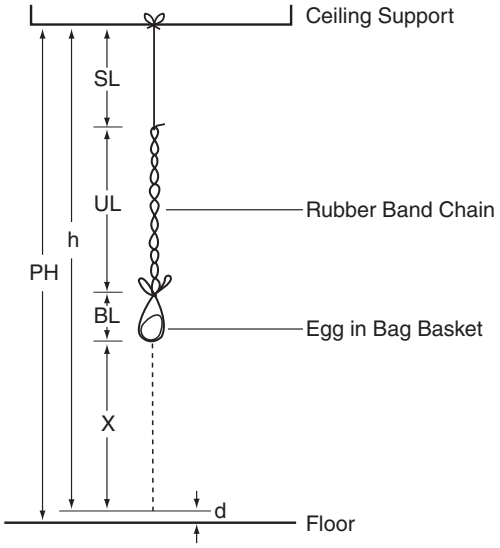

Figure 1.

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Materials

Balance, 0.1-g precision
C-clamp
Ceiling hook or rod support
Egg, raw (or hard boiled)
Marker, ink
Mass with hook, 100-g or 50-g
Meter stick
Paper towels
Rubber bands, 3–4″ long, 1/16″ thick, 10
Sandwich bag, plastic
Scissors
Step-stool
String, thin, 150 cm
Tape measure
Trough or catch bucket (optional)
Water

Safety Precautions

Wear safety glasses. If an egg cracks on the floor, clean up the spill immediately to reduce the risk of a slippery surface. Please follow all laboratory safety guidelines.

Procedure

1. Obtain ten long, thin rubber bands.
2. Link two rubber bands together with a "looping knot" as shown in Figure 2.
3. Make a chain of ten rubber bands using the "looping knot" method.
4. Hold the rubber band chain by one end and allow it to hang vertically. Measure the unstretched length with a meter stick. It may be necessary to pull the chain slightly in order to uncurl and untwist some of the rubber bands and get a more accurate "unstretched" length. Record the unstretched length to the nearest 0.1 centimeter.

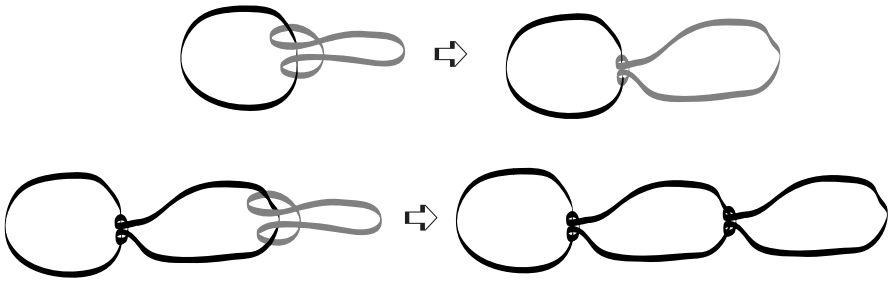

Figure 2.

Unstretched Rubber Band Chain Length (UL): _____.

5. Add a 100-g or 50-g hooked mass to one end of the rubber band chain.
6. Hold the other end of the rubber band chain and allow the mass to hang vertically.
7. With the meter stick, measure the length of the stretched rubber band chain. Record the stretched length to the nearest 0.1 centimeter.

Stretched Rubber Band Chain Length (S): _____.

8. Calculate the spring constant, *k*, for the rubber band chain using the following equation:

k = (mass of weight)(981 cm/s^2)/(S – UL)

Spring Constant *(k)*: _____.

9. Place an egg into a sandwich bag.
10. Measure the mass of the egg and sandwich bag using a balance. Record the mass to the nearest 0.1 g.

Mass of Egg and Sandwich Bag (M) _____.

11. Tie the sandwich bag closed with a free end of the rubber band chain. Use the same "looping knot" that was used to link the rubber bands together to connect the bag to the chain (Figures 1 and 2).

12. With a meter stick, measure the length of the egg basket from the end of the rubber band looping knot to the bottom of the bag. Record this measurement to the nearest 0.1 centimeter.

    Egg Basket Length (BL): _____.

13. *(For the teacher)* With a tape measure, measure, to the nearest 0.1 centimeter, the height above the ground of the ceiling hook or support rod, from which the bungee jump will begin. *Caution:* Take extreme care when standing on a step-stool.

    Platform Height (PH): _____.

14. Calculate the stretch distance of the rubber band chain using the following equation:

$$X = 2M\frac{(981\ cm/s^2)(PH-2\ cm)}{K}$$

    Stretch Distance, (X): _____.

15. Calculate the length of additional string that is necessary to successfully complete the jump safely (refer to the *Background* section). SL = h – UL – BL – X

    String Length (SL): _____.

16. Measure the string to the necessary length with a meter stick. Use scissors to cut the string about 10 cm beyond the necessary length to allow for excess string at each end for clamping and tying the string to the support rod and rubber band chain, respectively.

17. Securely tie one end of the string to the free end of the rubber band chain. Tie as close to the end of the string as possible.

18. Measure the string length from the end tied to the bag. Use an ink marker to mark the end point of the true, functional string length (calculated in step 15). Leave at least 5 cm of excess string at the end.

19. *(Optional)* Fill a trough with water to act as the pool or lake below the bungee-jump site. Place it beneath the "jump" location.

20. *(For the teacher)* Use a C-clamp to secure the free end of the string to the ceiling support or support rod. Secure the string so that the ink mark on the string is adjacent to the support rod "jumping platform." A C-clamp will allow for easier adjustment of the total length of the bungee cord, if necessary. If the string is tied to the support rod, use a slip knot. Be careful not to drop the bungee cord and break the egg.

21. Double check the total length of the bungee cord and egg basket. Make sure to lift the egg basket slightly until the rubber band chain begins to have some slack in order to determine the approximate unstretched length of the bungee cord.

22. *(For the teacher)* Raise the egg to the correct bungee-jump starting position (platform height).

23. *(For the teacher)* Release the egg.

24. Did the egg survive the bungee jump? Was it the most exhilarating ride possible? If not, what are some possible sources of error that may be corrected?

Tips

- Double check all the calculations before bungee jumping.
- Make sure the bungee cord does not get tangled up or twisted together before the release. Have a partner hold string apart and to the side before the drop. Let go of the string immediately when the egg is released.
- The *Background* section infers previous knowledge about the conservation of energy and Hooke's law. Please refer to your physics or physical science textbooks for more information about these topics.
- Plastic eggs filled with water with the two halves loosely connected may be used instead of real eggs. Place tape on one side to act as a hinge.
- A thin elastic band may be used instead of a rubber band chain. Cut the band so its length is ¼ to ⅓ the platform height.

Disposal

Please consult your current *Flinn Scientific Catalog/Reference Manual* for general guidelines and specific procedures, and review all federal, state and local regulations that may apply, before proceeding. All cracked eggs may be placed in trash according to Flinn Suggested Disposal Method #26a..

Connecting to the National Standards

This laboratory activity relates to the following National Science Education Standards (1996):

Unifying Concepts and Processes: Grades K–12
Systems, order, and organization
Evidence, models, and explanation
Constancy, change, and measurement
Content Standards: Grades 5–8
Content Standard A: Science as Inquiry
Content Standard B: Physical Science, understanding of motions and forces, transfer of energy
Content Standard F: Science in Personal and Social Perspectives; personal health; risks and benefits
Content Standards: Grades 9–12
Content Standard A: Science as Inquiry
Content Standard B: Physical Science, motions and forces, conservation of energy and increase in disorder
Content Standard F: Science in Personal and Social Perspectives; personal and community health; natural and human-induced hazards

Materials for the *Bungee-Jumping Egg* are available from Flinn Scientific, Inc.

Catalog No.	Description
AP6381	The Bungee-Jumping Egg Kit
AP1818	Rubber Bands, Medium, 750/pkg.
OB1091	Metric Weight, 100-g
AP8400	Tape Measure
AP4823	String, Thin
AP5352	Hooks, Ceiling, 2/pkg.

Consult your *Flinn Scientific Catalog/Reference Manual* for current prices.