The Bungee Omelet

A Freshman Engineering Design Project

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Overview:

In this project, student teams will develop a bungee jump **design** using theory coupled with experimental measurements of the parameters or variables necessary for accurately modeling. The bungee designs will be demonstrated in a competition to see which team's design performs the best. During the competition, visual and video tape evidence will be used to judge the closeness to the ground and to determine the maximum deceleration of the payload. For this project, the "jumper" will consist of an **uncooked egg** and the jump will be from the top of Sun Angel stadium.

Learning Objectives or Student Outcomes:

By the end of this project, students will be able to

- design a quality bungee cord experience that will allow a delicate object to come as close to the ground as possible without damage;
- demonstrate the team bungee designs in a competition to see which team's design performs the best; and
- work as a team to complete a detailed written project report.

Length of Lesson:

This project is generally one of three per semester. The actual time the project takes will depend upon a few factors, such as how much in-class time is devoted to the lesson, how much out-of-class time the instructor deems appropriate, and what other activities are happening during the duration of the project.

Team Size/Composition:

Teams of 4 work best; if necessary, a few teams of 3 or 5 students may be formed. Teams stay together for the length of the project.

How is *positive interdependence* ensured?

Positive interdependence is ensured through the completion of *one* design product and *one* team report. Students must really work together as a team in order to successfully accomplish their goal. Students receive a common grade for the project.

How is *individual accountability* ensured?

Students learn techniques and are given opportunities for giving each other constructive feedback about their performance as team members.

Peer evaluations are used to adjust the grades of individuals within the teams.

Assessment:

Assessment will be accomplished through

- the bungee jump competition (see Competition Day Deliverables),
- the final written report (see Report Guidelines), and
- peer evaluations.

NOTE: If the reports are going to be posted on a course web site, the students should turn in both a hard copy and an electronic version of the report.

Team Skills Needed for Success:

The teams need solid communication skills and the ability to work collaboratively—sharing ideas and giving and accepting constructive feedback.

How Are Team Skills Emphasized?

Teams are required to reflect upon and assess their internal processes as an ongoing part of the project.

Materials Needed by Students:

One meter lengths of cord (to be provided by instructor)

Other materials chosen by teams for the creation of their release devices

Instructions to Students:

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Project Overview

Bungee cord jumping attracts those persons who like the strong feeling of danger mixed with their entertainment. Jumps have been made from high bridges, tall cranes, and hot air balloons. Bungee cord jumpers step, dive, fall, or are pushed off these high perches with only one end of an elastic cord fastened to their bodies. The other end of the cord is supposed to be fastened to the device from which the jump is made.

During the first part of the jump, jumpers are pulled toward earth by gravity, accelerating in free fall, much like a sky diver. For the jumper, this free fall is related to the quality of the jump - the desire is to free fall for as long as possible and to reach a speed that is as high as possible. But, the free fall continues only as long as the bungee cord remains slack. When the slack is gone and the bungee cord begins to stretch, the cord applies an upward force that begins to decelerate the jumper. This decelerating force increases as the bungee cord is stretched farther and farther. If all goes well, jumpers are brought to a stop before the space between them and the ground shrinks to zero.

The sport of *bungee cord jumping* is now on the wane, partially due to the rise in legal cases as a result of injuries and partially due to the fad running its course. However, physics, math, and engineering are involved in successfully designing a "good" bungee jump so that is what this lesson is going to teach you to do. The purpose of this project is to integrate these three disciplines together to understand better how they relate to one another.

In this project your team will be expected to develop a bungee jump **design** using theory coupled with experimental measurements of the parameters or variables necessary for accurately modeling. Your team's first prototype will be the one which is actually used in the competition, to be described later. This is in keeping with the new decision paradigm which says that to be globally competitive, one must strive to model the complete artifact and its manufacturing process so that the first one manufactured

	can go to the customer. The goal of this project is to design a quality bungee cord experience that will allow a delicate object to come as close to the ground as possible without damage. Damage can be incurred by: • actually impacting the ground, or • decelerating the object too rapidly The bungee designs will be demonstrated in a competition to see which team's design performs the best. During the competition, visual and video tape evidence will be used to judge the closeness to the ground and to determine the maximum deceleration of the payload. For this project, the "jumper" will consist of an **uncooked egg** and the jump will be from the top of Sun Angel stadium. The egg is vulnerable - if it strikes the ground, it will experience the HD syndrome.
2	**Performance Modeling** Your team's performance model should aid you in picking a design that best meets the constraints and objectives of this project. The model will contain a variety of variables and parameters which your team must specify. **Modeling the physics of the jump** There are several variables of importance in the jump. At this stage in your physics education, you have learned about Newton's Laws of Motion. This project will provide you an excellent opportunity to apply these laws in an engineering context. To model the physics of the jump, your team must begin with Newton's Second Law applied to the jumper. The forces in this equation will be somewhat complicated, since the force applied by the bungee cord will act only when the cord is stretched. But, at this stage of your mathematics education, you have learned about the use of Excel spreadsheets to solve a variety of problems, so here is an excellent opportunity to apply this knowledge (and the the use of some new Excel functions) in an engineering context, again. A quantity of importance is the maximum deceleration encountered by jumpers as the bungee cord stops them. If this deceleration is too great, it may cause damage to the jumper. The maximum deceleration is reached when the net force on the jumper is a maximum. The force **must not exceed three times the weight of the jumper**. **Modeling the properties of the cord** Elastic materials such as rubber consist of long chain molecules that deform when stretched and recover when released. The processing of these materials determines, among other properties, the relationship between the amount of stretch and the force causing the stretch. The number of cross-links formed through covalent bonding between the long chain molecules can be increased, for example, to decrease the amount of stretch for a given force. Elastic materials with few covalent bonds can easily

	stretch in one direction to three or four times their original length without damaging the material. Rubber materials change their properties *over time* and *with use* as the bonds change. The bungee cord enters into the modeling equations of the previous section through the relationship between the force used to stretch the cord and the amount it stretches. It is quite common to use the model of a linear spring having a constant "spring constant" which is the proportionality between the force causing the stretch and the amount of the stretch. This linear model is known as Hooke's Law. However, rubber is not truly a linear substance and you will want to describe fully the functional relationship between the force and the displacement (stretch). Your modeling must include this functional relationship. Your team must make a series of measurements on one or more of the one meter lengths of cord which will be provided to you. You should use a variety of weights to apply static loads to stretch the cord being tested to find the functional relationship between the force and the stretch. A weight (or weights), which act as the stretching force, is (are) to be tied or fastened to the samples of latex cord, as depicted in this figure. The unstretched lengths are measured, then the stretched lengths for various values of the force are measured so that the functional relationship is deduced. This spreadsheet may assist your team in carrying out this portion of the design process. **Solving the models** Your team will combine the physics model and the bungee cord model into one model that you will solve with an Excel spreadsheet. You are to use Euler's method to solve the equations, which is the method employed in Model #3, in solving Newton's Law of Cooling. Additional help will be provided in class.
3	## What You Are to Design **The release device** Your team must design a device that will hold the egg on the end of the patented Foundation Coalition Bungee Omelet Swingarm. The design and dimensions of this swingarm will be given to your team; a picture of the swingarm is shown here. Your release device must allow you to release the egg from rest, remotely. Complete sketches of your design must be approved by the engineering instructor before you build it. The release device must then be built according to your plans and will be used by your team in the bungee drop competition. It must be compatible with the FCBO Swingarm and be installable in five minutes or less. **The cord** The principle design variables that you will ultimately have to specify are: • The unstretched length of the cord that you will use in the competition, including the extra length needed at the ends for fastening • The number of strands of the cord you will use

4	**Important Guidelines** From previous experience the engineering instructors have discovered that: • You should not over-stretch the strands given for testing. That is, you should not stretch the samples to more than three times their original length. In fact, exceed two times their original length as infrequently as possible. • You should avoid touching the strands with your bare hands. Oils on your skin have a deleterious effect on the latex strands. Gloves will be provided for handling the samples. • You should keep the samples out of contact with the air - keep them in the brown bag provided. • Although you should stretch each cord a few times before testing, do not put a lot of test cycles on the long strands given to you for testing.
5	**Competition Day Deliverables** On competition day, you will need to have ready: • The number of strands and their length • An operational release mechanism, including a plastic bag to reduce the HD factor
6	**Written Report** See Report Guidelines for specifics regarding the team written report.

Handouts:

- Report Guidelines
- Important Parameters

Report Guidelines

The report is to be done in *Lab Format*, not as an essay. The following sections should be included, and each section title should be highlighted:

- Introduction
  - Purpose of project
  - Goals
  - Motivation
- Modeling Process
  - Measuring the elastic properties of the bungee cord
  - Presenting and analyzing the bungee cord data
  - Use of Euler's method on spreadsheet
  - Strategy for determining the number of cords, lengths, etc.
  - Predictions of the model
    - Closest approach to ground
    - Maximum deceleration
    - Final location of egg at steady state
- Design Process
  - Preliminary designs (Use sketches or CAD drawings here) of launching mechanism
    - Concept combination table
  - Modifications
  - Brainstorming (if carried out)
- Results of the Bungee Jump
  - Capturing the data
  - Presenting and analyzing the data
- Discussion and Analysis
  - Comparison of prediction and measured results
  - Evaluation of the project

As before, the report should be descriptive and must use proper grammar, spelling, sentence structure, and so on. It should also be illustrative and use graphs, sketches, figures, and so on as necessary. You want the report to be clear and concise, so that you could pick it up ten years from now and be able to understand what your team has done.

Important parameters

Parameter	Value	Units
Height of stadium	18.29	meters
Drag coefficient	0.5	dimensionless
Air density	1.2	kg/m^3