Bungee Barbie – Teacher Notes

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Introduction:

This investigation is for the adrenaline junkies out there! Bungee jumping can be both exciting and terrifying, but it cannot be conducted in an ad-hoc way. There is a lot of planning and testing in place for jumpers to stay safe. This engaging topic forms the basis of this open-inquiry investigation. Students will be asked to use experimentation to make well-informed predictions. Students will be engaged further when able to explore the interesting physics that underpin a bungee jump.

Student's scientific skills will be put to the test in order to compete for which team can make the most accurate prediction. Students will be asked to devise a method and choose how best to record and analyse their results. Refining these skills will give students the edge required to be successful. This competition will also highlight to students the value of evaluating one's experiment in terms of its reliability.

The topic of bungee jumping introduces students to a valuable discussion on the forces at play in this system of energy. Year 7 students will benefit from seeing how the bungee jump starts off in a balanced state. Once the rider jumps, students can see a dramatic display of unbalanced forces acting upon one another until these forces settle back into a balanced state. Year 8 students can enjoy trying to identify all the energy transfers and transformations taking place, such as the transformation from gravitational potential energy to elastic potential energy. Year 9-10 students will benefit from seeing how air resistance drags on the system, causing the efficiency of that system to be less than 100%.

This investigation is highly adaptable as teachers may choose to include various items to give students more concrete guidance. This can be in the form of tables and graph plots. Teachers may also choose to make this investigation even more open and exploratory by not requiring that students write a method beforehand. Further suggestions are offered throughout.

Questions:

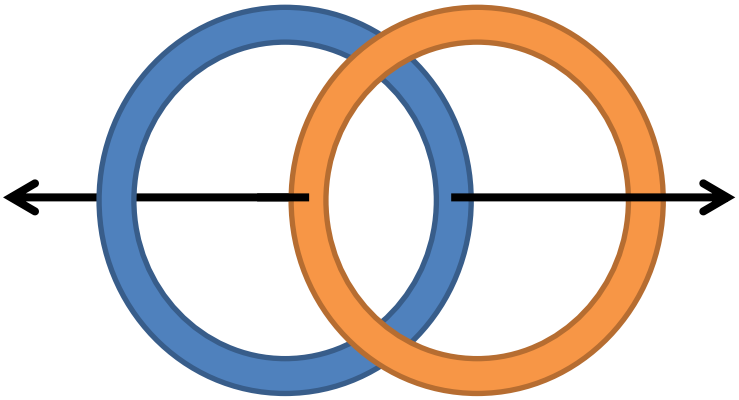
Students are given this question: **What is the optimal number of rubber bands to use for a two-story bungee jump with a Barbie® doll as a test dummy?** They are given the objective to come as close as possible to the ground without actually hitting it.

A suitable two-story jump site will have to be chosen. Student safety and visibility are considerations. Suggestions for this are a balcony with high railings or a window with a high sill. For time constraints, it is recommended that students are given the exact height of the proposed two-story jump, however if students require practice in taking various measurements, then this step can also be part of the investigation.

Students will then be asked to write an Aim and a Hypothesis. These will highly reflect the scientific question being asked. Students may choose to make preliminary calculations in order to include a prediction in their Hypothesis, such as measuring the "stretched" length of one rubber band and using that number to divide the length of the two-storey jump.

Plan:

Students are given a materials list and told to write their own method. Students can have a play around with what they have been given to help them brainstorm an effective experimental method. The following suggestions can be given to help students with their procedures.



Students may be playing around with the idea of how best to tie the elastics together. Teachers may demonstrate the "zen diagram" method, as demonstrated in the picture to the left. Discuss with students why this is the superior technique when considering the integrity of the bungee cord, as well as the consistency required for making scaled-up predictions. It is recommended that teachers inspect how students have tied the bungee cord to the test dummy. It must be at least double knotted, preferably at the feet. This will minimise the hazard of falling objects.

If students are measuring the height of the competition drop, they can do this with a tape measure from a hardware store. A soft tape measure, such as that used in tailoring, is more appropriate for smaller drops because students can 'Blutack' it to a piece of cardboard, or a piece of furniture. A square ruler is an important tool that allows students to ensure that the tape measure aligns perpendicular to the floor. Students may choose to utilise this tool, or choose to "eyeball" this step instead as this is less fiddly. Discuss with students how forgoing measuring tools or "cutting corners" can affect the accuracy of their results.

As students devise their method they will have to define their independent (number of elastics) and dependent (farthest distance that the test dummy falls) variables. You may also ask students what their controlled variables are and what considerations they are taking to keep them consistent. Some good-practise suggestions are having multiple students take the jump measurements, testing as wide a variety of bungee lengths as possible, and performing multiple tests for each bungee length and finding an average.

Take it up a notch by offering students small round red stickers. These can act like test dummy spots. Students can think about how using these can help them take more accurate measurements (especially when using video to record results).

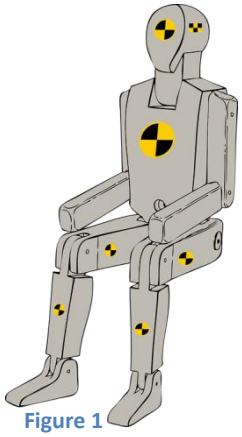


Figure 1

Conduct:

Observe the movement of the test dummy. Encourage students to write qualitative as well as quantitative results. Teachers may ask the following questions to initiate this process, such as: does it matter if the test dummy is forcefully pushed off the threshold versus gently dropped? **AND** how many times does the test dummy change direction? Observations on the test dummy's movement will help students during the Problem Solving section as they break-down the components of this energetic system.

To minimise human error when recording measurements, students can be encouraged to do multiple trials, and then calculate an average. If extra guidance is required, the following table can be provided to students:

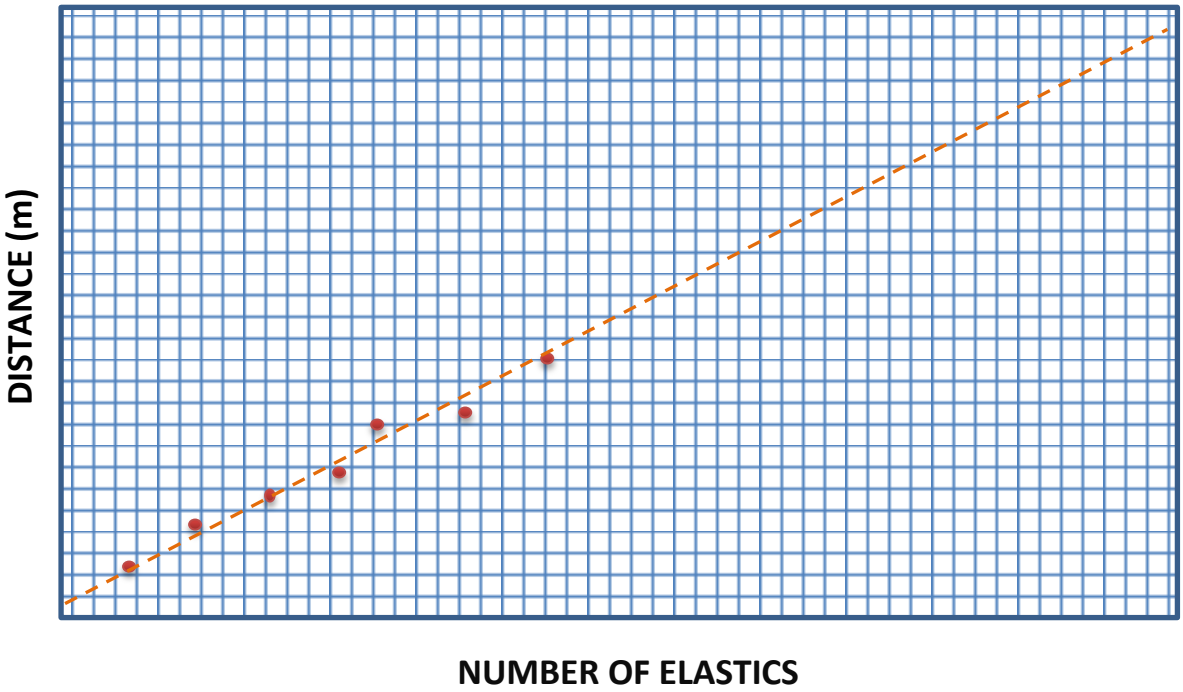
No. of Elastics	Distance Fallen (m)				Observations
	1st Trial	2nd Trial	3rd Trial	AVERAGE	
2					

After students have finalised their analysis, they will have to construct the bungee cord that they will compete with. This cord will be made up of many more elastic bands. The final test using the two-storey jump can then be conducted. For each test teachers may allocate a student from the lab group being tested and a student from another group to umpire each fall. Alternatively, teachers may set-up a video camera in order to get the most accurate results for the competition.

Analysis:

For students to make a good prediction they will have to plot their results in a graph with the below axis. The graph will also need to have a large enough scale to include the two-storey jump. Students must then find the line of best fit. They can find this by using a ruler and the "eyeballing" method. Advanced students may want to use their mathematic skills to find a linear equation (y=mx+b) using the data points for a more accurate prediction.

Students can enter their results in excel and allow the program to find their line of best fit. Do this by selecting a scatter graph and then using the Trendline function under Layout, which is found under Chart tools.



Once students have their line of best fit, they can then find which point on the line matches up with the two-storey jump distance. This will tell them how many elastics are required. They will need to round down the number of elastics so that the test dummy does not hit their head on the ground!

Problem-Solving:

At this stage students can evaluate whether their experimental design was satisfactory. Did they test the correct things in order to give themselves the most predictive power? Did they conduct a fair-test? Did students ensure that the controlled variables remained consistent throughout, such as the weight of the test dummy or the environmental conditions? Strong wind can have a significant effect on the bungee jump, while temperature changes can impact the tensile properties of the elastics. Did students try to minimise human error by

taking multiple measurements? Did students optimise their measurement-taking by positioning themselves so that they had the best line of sight for each test? Allow students to think of ways to improve the experiment if time and resources were not an issue.

Motivate students to **explain the movement of a bungee jump using their theoretical knowledge**. Can Year 7 students explain the movement of a bungee jump by identifying the role of gravity and all the balanced and unbalanced forces at play? Can Year 8-10 students explain the movement of a bungee jump as a system of energy? Below is an example explanation that students can work towards:

There are multiple phases of a bungee jump. The **first phase** is when the rider is standing on the threshold while being attached to the bungee cord. There is no movement; therefore all the forces are balanced. Gravity is balanced with the equal and opposite reactive force of the bridge holding up the bungee jumper.

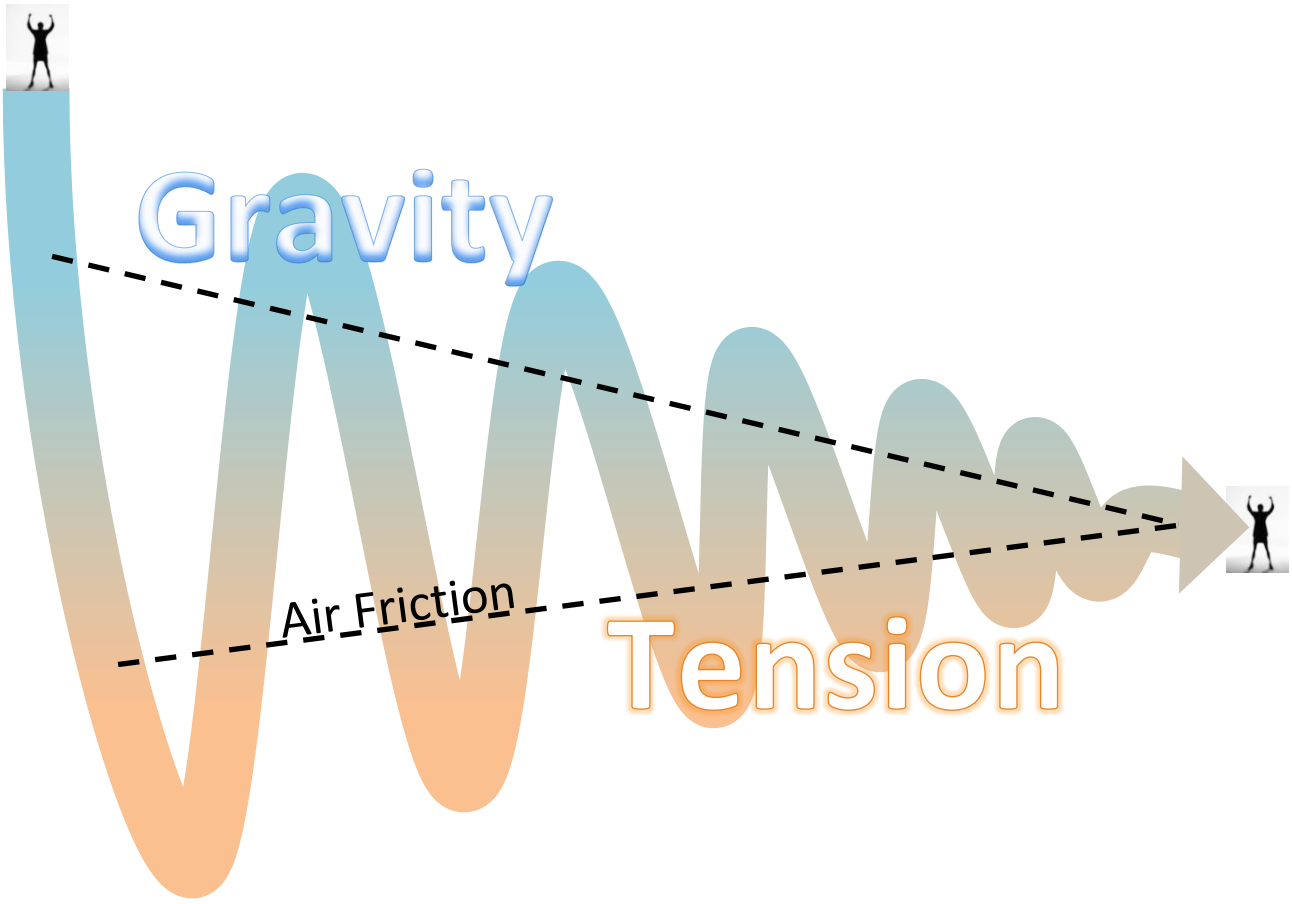
The **second phase** is when the person jumps off the bridge. At the moment the person jumps, the gravitational potential energy is at its highest. There is usually quite a lot of distance that the jumper will fall as the bungee cord has slack left in it. During this time the jumper is in "free-flight". This means that gravity is the predominate force acting on the jumper, as they are accelerated towards the earth via kinetic energy. Air resistance is also occurring, slowing down the acceleration and causing efficiency losses.

The **third phase** occurs when the bungee cord has no more slack and begins to stretch. The force of gravity is starting to be countered by the upwards force of tension. As the bungee cord stretches further and further, it begins over-powering the force of gravity to the point where the jumper quickly slows down and stops. At this point the elastic potential energy is at its greatest.

The **fourth phase** is when the jumper changes direction, and the elastic potential energy transforms into an upwards kinetic force experienced by the jumper. The retraction is usually so great that the jumper is propelled high enough in the air that there is once again slack in the bungee cord. Because of this, there is a repeat of the phases starting with the second as the bungee jumper experiences free-flight once again.

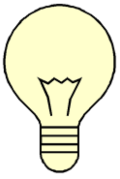
The kinetic energy experienced by the rider occurs due to the energy transformations between gravitational potential energy and elastic potential energy. This can occur indefinitely, causing the jumper to continuously fall and be propelled upwards only to fall again. However, this is not the case in reality due to efficiency losses from air resistance. Eventually the bungee jumper will become stationary as all the forces become balanced once again.

Allow students to come up with an energy flow diagram that describes the above. Encourage students to include as many components as possible by getting creative! They can draw it or use the Word Art and Drawing functions in Microsoft Word to do this. Below is an example:



Conclusion:

Students can now ask themselves if their Aim achieved. Was the prediction made in their hypothesis close to being correct? Were students able to make a more accurate prediction after they had done their experimental analysis? Students can write concluding statements about how they did in the competition, and include some information about the winning team's prediction, if it wasn't them.



What do real bungee jumpers use for bungee cord? Bungee cord used for jumping is very heavy duty. It usually consists of hundreds of strands of rubber enclosed in a woven sheath made of cotton and/or polyester. The most common bungee cords stretch 2 to 4 times its original length! Students can research this and more to include in an interesting poster.

References:

Figure 1 - OpenClipart-Vectors, https://pixabay.com/en/car-crash-dummy-mannequin-road-2029640/, CC0 Creative Commons: https://pixabay.com/en/service/terms/#usage