Bungee Barbie: Teacher Notes

Overview/Introduction

The article, *the physics of bungee jumping*, gives an excellent overview of the history of this physics problem (Menz, 1993). The physics of bungee jumping is quite complicated. It is relatively easy to experimentally verify that the bungee jumper experiences a downward acceleration that is greater than the acceleration due to gravity (for example, Heck et al, 2010), but the explanation of this phenomenon was developed over a number of years by a number of researchers (for example, Calkin et al, 1989; Schagerl et al, 1997; Strnad, 1997; Kockelman & Hubbard, 2004; Wong & Yasui, 2006).

There is a fun video of the Wile E. Coyote and Road Runner (O'Callahan, 2010) which can be used to introduce this activity. <www.youtube.com/watch?v=_9ieb1Y1VCY>.

Curriculum Outcomes: Victorian Curriculum F-10

Levels 7 and 8

Science Understanding: Physical sciences

- Change to an object's motion is caused by unbalanced forces acting on the object; Earth's gravity pulls objects towards the centre of Earth (VCSSU103)
- Energy appears in different forms including movement (kinetic energy), heat, light, chemical energy and potential energy; devices can change energy from one form to another (VCSSU104)

Levels 9 and 10

Science Understanding: Physical sciences

- Energy flow in Earth's atmosphere can be explained by the processes of heat transfer (VCSSU132)
    - recognising that the Law of Conservation of Energy explains that total energy is maintained in energy transfers and transformations
    - recognising that in energy transfers and transformations, a number of steps can occur and the system is not 100% efficient so that usable energy is reduced
    - comparing energy changes in physical events, for example, car crashes, the motion of pendulums, lifting and dropping
- The description and explanation of the motion of objects involves the interaction of forces and the exchange of energy and can be described and predicted using the laws of physics (VCSSU133)
    - recognising that a stationary object, or a moving object with constant motion, has balanced forces acting on it
    - gathering data to analyse everyday motion produced by forces, for example, measurements of distance and time, velocity, mass, acceleration and force
    - investigating the effects of applying different forces, including Earth's gravitational force, to familiar objects

Key Concepts

Force – a push or a pull

Tension force – a pull stretches an object to try to make it bigger or longer.

Newton's First Law – Objects at rest stay at rest. Objects in motion stay in a straight line motion unless subjected to an unbalanced force.

Newton's Second Law – The net force acting on an object is equal to the mass of the object multiplied by its acceleration:
F=ma

Newton's Third Law – When one object exerts a force on a second object, the second object exerts an equal and opposite force back on the first object.

Kinetic energy – Energy that an object has by virtue of its motion.

Potential energy – Energy that is stored in an object has by virtue of its position.

Elasticity – The ability of an object or material to resume its normal shape after being stretched or compressed; stretchiness.

Energy loss – When energy is transformed from one form to another, there is some energy loss.

Background information

Experiment history

The Internet has several variations of an activity called either *Barbie Bungee* or *Bungee Barbie*. Essentially, the activity is an exercise on linear regression (line-of-best-fit plots), in which students plot the extension of a set of rubber bands as a function of the number of rubber bands. The earliest version seems to one from a series of workshops called *Stepping Stones to Mathematical Modeling*, developed by Indiana University, Bloomington (1993-1995). However, many versions seem to based on the version by themathlab.com (1999-2010). There is a video by Roda (2012), which shows this activity being completed in a single class lesson by year-8 students. ASTA Science ASSIST (no date) also has a version using an egg in a zip-lock bag.

More challenging science activities, which involve the physics of bungee jumping, depends on measuring velocities and acceleration, and possibility linked to (more) sophisticated mathematical analysis (for example, Menz, 1993; Martin & Martin, 1994; Kagan & Kott, 1996; Biezeveld, 2003; Taylor, no date; Horton, 2004; Turner & Taylor, 2005; Heck et al, 2010).

A version of this activity, called *Barbie Bungee*, has been run at Mercy Regional College, Camperdown for a few years. It was very prescriptive and similar to versions found on the internet (Indiana University, 1993-1995; themathlab.com, 1999-2010). This version is less prescriptive, and incorporates more inquiry.

Pedagogy

Inquiry

This is an inquiry activity that can be adjusted by the teacher to be as guided or as open-ended as desired. The student notes begin with

specific directions but later questions allow students to conduct more independent investigations. The teacher may, however, decide to provide close guidance and direction throughout the activity.

Teachers may use the inquiry scaffolding tool[1] to assist decision making about the degree of support to provide students for each phase of the inquiry process.

[1] Inquiry scaffolding tool. National Research Council (2000); Bruck, L.B., Bretz, S.L., & Towns, M. H.,2008. Adapted for the Victorian Curriculum by Lim, K. F. (2016), unpublished.)

Inquiry Scaffolding Tool

Years 7-8 Tool

Curriculum outcome (slightly paraphrased)	Structured Inquiry	Guided Inquiry	Open Inquiry	Prescription	Confirmation	Curriculum outcome (slightly paraphrased)
Identify questions (VCSIS107)	Student sharpens or clarifies a question provided by teacher, or other source	Student selects among questions, poses new questions	Student poses a question	No question	Student engages in a question provided by teacher, or other source	Identify questions (VCSIS107)
Plan and conduct investigation (VCSIS108)	Student sharpens or clarifies a plan provided by teacher	Student selects among plans	Student plans and conducts investigation	Student is given plan of investigation	Student uses a plan provided by teacher	Plan and conduct investigation (VCSIS108)
In fair tests, select equipment to collect data (VCSIS109)	Student is told how to select equipment for a fair test	Student selects among equipment	Student selects equipment	Student is given data	Student is told how to use equipment to collect data	In fair tests, select equipment to collect data (VCSIS109)
Construct and use representations, to record and summarise data (VCSIS110)	Student is guided to represent and summarise data	Student selects among representations and summaries	Student determines and uses representations and summaries	Student is given representations and summaries of data	Student told how to represent and summarise data	Construct and use representations, to record and summarise data (VCSIS110)
Identify relationships, evaluate claims and draw conclusions (VCSIS111)	Student is given relationships and evaluations, and guided towards conclusions	Student is directed to evaluate claims and selects among possible conclusions	Student evaluates claims and draws conclusions	Student is given conclusions	Student is given relationships and evaluations, and told how to draw conclusions	Identify relationships, evaluate claims and draw conclusions (VCSIS111)
Reflect on the method used and evaluate data (VCSIS112)	Student told how to reflect and evaluate	Student is guided toward reflection and evaluation	Student reflects on the method and evaluates data	Student is given evaluation	Student is given reflection and told how to evaluate	Reflect on the method used and evaluate data (VCSIS112)
Communicate ideas, findings and solutions to problems , using scientific language (VCSIS113)	Student is provided broad guidelines to use to sharpen communication	Student is coached in development of communication	Student communicates ideas, findings and solutions	No communication	Student is given steps and procedures for communication	Communicate ideas, findings and solutions to problems , using scientific language (VCSIS113)

Aspects of Inquiry (Victorian Curriculum, Levels 7-8)

Years 9-10 Tool

Curriculum outcome (slightly paraphrased)	Prescription	Confirmation	Structured Inquiry	Guided Inquiry	Open Inquiry	Curriculum outcome (slightly paraphrased)
Formulate questions or hypotheses (VCSIS134)	No question	Student engages in a question provided by teacher, or other source	Student sharpens or clarifies a question provided by teacher, or other source	Student selects among questions, poses new questions	Student poses a question	Formulate questions or hypotheses (VCSIS134)
Plan, select and use appropriate investigation (VCSIS135)	Student is given plan of investigation	Student uses a plan provided by teacher, or other source	Student sharpens or clarifies a plan provided by teacher, or other source	Student selects among plans, poses new plans	Student plans, selects and uses appropriate investigation	Plan, select and use appropriate investigation (VCSIS135)
Select and use appropriate equipment and collect and record data (VCSIS136)	Student is given data	Student is told how to use equipment and how to collect data	Student is told how to use equipment and asked to collect data	Student is directed to collect certain data and selects appropriate equipment	Student determines what is appropriate equipment and data and collects data	Select and use appropriate equipment and collect and record data (VCSIS136)
Construct and use representations, to record and summarise data (VCSIS137)	Student is given representations and summaries of data	Student told how to represent and summarise data	Student is guided to represent and summarise data	Student selects among representations and summaries	Student determines and uses appropriate representations and summaries	Construct and use representations, to record and summarise data (VCSIS137)
Analyse patterns and trends in data, and draw conclusions (VCSIS138)	Student is given conclusions	Student is given trends in data and told how to draw conclusions	Student is given trends in data and guided towards conclusions	Student is directed to analyse data and selects among possible conclusions	Student analyses data and draws conclusions	Analyse patterns and trends in data, and draw conclusions (VCSIS138)
Use knowledge of scientific concepts to evaluate conclusions (VCSIS139)	Student is given links to scientific concepts and given evaluation	Student is given scientific concepts and told how to evaluate	Student is given scientific concepts and asked to evaluate	Student is directed toward areas and sources of scientific knowledge	Student independently examines other resources and evaluates conclusions	Use knowledge of scientific concepts to evaluate conclusions (VCSIS139)
Communicate scientific ideas and evidence-based arguments (VCSIS140)	No communication	Student is given steps and procedures for communication	Student is provided broad guidelines to use to sharpen communication	Student is coached in development of communication	Student forms reasonable and logical argument to communicate explanation	Communicate scientific ideas and evidence-based arguments (VCSIS140)

Aspects of Inquiry (Victorian Curriculum, Levels 9-10)

Some inquiry questions

- For a given height of the "jumping platform", what combination of length of string and rubber bands will get Barbie closest to the ground/floor without injury?
- How elastic is the "rope"? What combination of length of string and rubber bands will result in the greatest number of bounces?

Things to discuss

What constitutes a "fair test" and "controlled variables? Is it necessary to replace the rubber bands after each bungee jump?

Extension suggestions

It is possible to involve different combinations of rope and rubber band. For example:

- Is there an optimal thickness of the rubber bands?
- Do two rubber bands linked in parallel give different dynamics to two rubber bands linked in series?
- Does the elasticity of the rubber bands change the dynamics of the bungee jump?
- Does a chest harness give different behaviour to a leg harness? What about attaching the rubber bands to the arms (à la Spiderman)?

Other inquiry questions:

- Does the jumper's mass and shape change the dynamics of the bungee jump? (Note [2].)
- How can the height of the rebound be maximised?

It is possible to measure velocity (or high speed video, or strobe lighting) to compare the acceleration of the bungee jumper with a freely falling object/body. This works best with a heavy rope/chain. If the rope/chain is heavy enough, a heavier jumper will fall slower than a lighter jumper (for the same rope/chain)!

Another possibility is to investigate systems that fall either faster or slower than free fall, and to relate these back to conservation of energy. The bungee jumper falls faster than freefall. A yoyo (or roll of toilet paper) will fall slower than freefall. Just imagine throwing/dropping rolls

[2] Having a variety of dolls adds to interest and permits inquiry questions such as "Does the jumper's mass and shape change the dynamics of the bungee jump?"

of toilet paper off the top floor! The students would love it, but the school administration and the cleaners might not.

References

A simple line-of-best-fit activity

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