**Bouncing ball video analysis: Day 1 of the Kangaroo Locomotion Case Study**

Names:

**Introduction**

Mechanical energy describes the ability of an object to do work. From a bowling ball knocking down pins, to a frog catching a fly with its tongue, mechanical energy underlies the movement we see all around us in everyday life. Although energy cannot be created or destroyed, it can change forms in two ways: (1) Energy transformation takes place when energy within a system changes from one form to another. For example, a frog’s tongue acts like a loaded spring, rapidly converting elastic potential energy to kinetic energy when the tongue shoots out to catch its dinner. (2) Energy transfer takes place when energy is exchanged from one system to another. For example, when a bowling ball collides with the pins, it transfers some of its kinetic energy to them, setting them in motion.

In today’s video analysis lab, we’ll observe, track and describe the motion of a bouncing ball. By recording the position and velocity as a function of time, we can calculate the gravitational potential energy and kinetic energy in order to investigate how each quantity changes throughout the ball’s motion.

**Some useful definitions:**

* Kinetic energy: Energy associated with motion, described by $KE=\frac{1}{2}mv^{2}$
* Gravitational potential energy: Stored energy associated with location in a gravitational field, described by $PE\_{g}=mgh$
* Elastic potential energy: Stored energy associated with stretching or compressing a spring or another spring-like material, described by $PE\_{s}=\frac{1}{2}kx^{2}$

**Objectives:**

* Describe how the position vs. time and velocity vs. time graphs correspond to the observed motion in the video.
* Use data from the video to elucidate energy transformations that take place while the ball is in motion.
* Determine whether the ball transfers energy to its surroundings, and identify when energy transfer takes place.

**Central questions:**

* What forms of mechanical energy does the ball have throughout its motion?
* When does the ball exchange energy with its environment?

**Predictions:**

1. Download the “Bouncing ball” movie from Canvas under > Files > Movies for video analysis.
2. After watching the movie, predict what the vertical position versus time (y vs. t) plot will look like for the ball’s center of mass while it is bouncing. Sketch your prediction plot below.

Predicted motion plot:

1. What forms of mechanical energy do you think the ball has at each of the following points throughout its motion? Explain your reasoning.
	1. The instant it is released from rest:
	2. As it falls toward the floor:
	3. While it is in contact with the floor:
	4. After it rebounds and is on its way up:
	5. When it reaches its top height after rebounding:

**Data collection: Position and Velocity**

1. Open Tracker, go to “Import” and navigate to where you have saved the movie. If you’re not sure where it is saved, try looking in the “downloads” folder.
2. Following the directions in the video analysis tutorial for collecting data from a movie, obtain the Vertical position vs. time (Y vs. t) and Vertical velocity vs. time (Vy vs. t) plots for the ball as it bounces at least 4-5 times.
3. Copy and paste your Time, Vertical Position (Y), and Vertical Velocity (Vy) data columns into *Excel*.
4. Prepare line plots of (Y vs. t) and Vertical velocity vs. time (Vy vs. t) in Excel and add axis labels. Ask if you need help with this. Print this graph, cut it out and tape it here:
5. In the next section, you’ll use this data to calculate the ball’s mechanical energy. First, let’s examine the position and velocity graphs.
	1. In what portion of the ball’s motion is the velocity positive?
	2. In what portion of the ball’s motion is the velocity negative?
	3. Is the velocity every zero? If so, when does this happen?
	4. Can you explain how the velocity in each part of the motion described in (a-c) corresponds to changes in the ball’s vertical position observed in the Y vs. time plot?

**Data analysis: Mechanical energy**

1. You can calculate Gravitational potential energy and Kinetic energy directly from the raw data in the following way:
	1. Add a column in Excel labeled Gravitational Potential Energy (J). In the first cell, enter the formula “=m\*g\*h”, where m is the estimated mass of the ball, g is the gravitational acceleration constant 9.8m/s2, and *h* is the current vertical elevation above the floor. Ask for help if you’re not sure how to enter the formula into Excel. Once you’ve entered this formula, select the bottom right corner of the cell with your mouse and drag it down to make the formula fill down through all the other cells in the column.
	2. Add a column in Excel labeled Kinetic Energy (J). In the first cell, enter the formula “= 0.5\*m\*Vy^2”, where m is the ball’s estimated mass, and Vy is the vertical velocity. As before, select the cell and drag down to fill in for other rows.
	3. Add a column in Excel labeled “Sum of Gravitational Potential + Kinetic Energy (J)”. In the first cell, enter a formula that adds the current values of Gravitational Potential Energy and Kinetic Energy from the adjacent columns. As before, select the cell and drag down to fill in the formula for other rows.
2. Make a line plot that shows the Gravitational Potential Energy vs. Time, Kinetic Energy vs. Time, and Sum of Gravitational + Kinetic vs. Time all together in the same figure. Add appropriate vertical and horizontal axis labels, and include a legend that identifies each data set. Print this graph, cut it out and tape it here:
3. On your printed graph of mechanical energy, label by hand some time points corresponding to each of the situations described below (label as a, b, c, etc). For each one, describe here what is happening with the gravitational potential energy and the kinetic energy. (For example, “Gravitational potential energy is [increasing/decreasing/zero], Kinetic energy is [increasing/decreasing/zero]”.
	1. As it falls toward the floor:
	2. While it is in contact with the floor:
	3. After it rebounds and is on its way up:
	4. When it reaches its top height after rebounding:
4. During which parts of the ball’s motion (if any) does the sum of gravitational potential energy and kinetic energy stay relatively constant?
5. During which parts of the ball’s motion (if any) does the sum of gravitational and potential energy change significantly? Where do you think the energy is going during these times?
6. How does the total mechanical energy (gravitational + potential) while the ball is in the air change from one bounce to the next?
7. Based on your data and your answers to the discussion questions, write a short paragraph summarizing energy transformations and energy transfers that take place for a bouncing ball.