SPRING ENERGY LAB

NIALL DALTON

INTRODUCTION

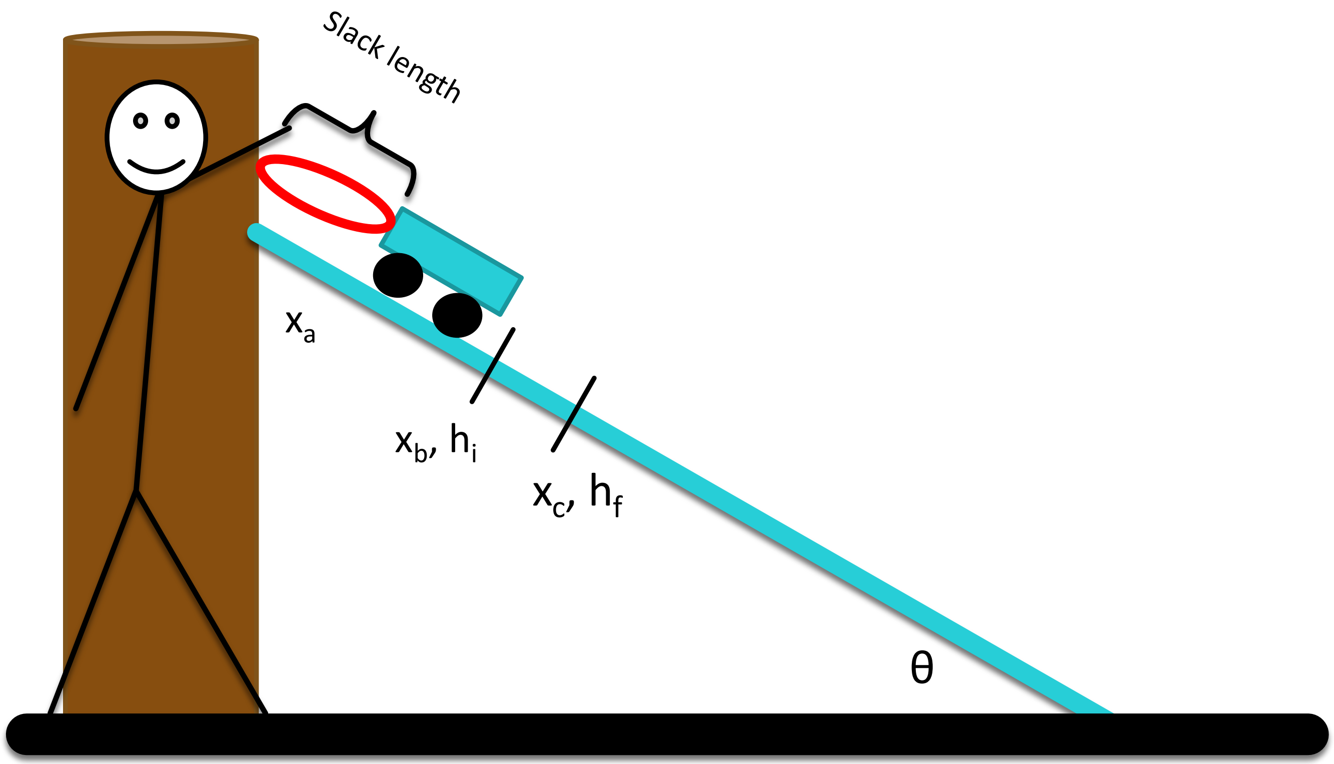
The purpose of this lab is to test the how stopping distance of a system on a ramp is affected by a bungee apparatus. Specifically, how does increasing a ramp angle affect the max displacement of a frictionless car that is attached to the top of the ramp with a bungee? It was hypothesized that displacement increases with ramp angle as described by the following equation:

$$\Delta x = 0.08233(\sqrt{\sin\theta * (\sin\theta + 31.0895)} + 0.082334 * (\sin\theta))+0.771$$

PROCEDURE

- We first measured the amount of slack in the bungee. After, we gathered a steel ramp, a frictionless car, and string. We attached the car to the bungee with string and we attached the other end of the bungee to a post with string. We set up the ramp at a specific angle against the post by using a level on Niall's phone. We then measured the initial position of the car on the ramp when the bungee had no slack and the car was at rest. Then we put the car at the top of the ramp and Niall said "Ready, set, go", and released the car on go while Celine held the bungee at the top of the ramp using string wrapped around the post. George measured and recorded where the car stopped by approximating with his vision where the car stopped on the ruler built into the ramp. The dropping and subsequent steps were repeated a total of ten times for that specific angle, and again 10 times each for 4 more specific angles.
- We found our k value by finding the average force over 5 different distances both before and after the car trials. We then averaged the force for before and after and found the slope of an average force vs. displacement graph, which represents k (Appendix C).

DIAGRAM

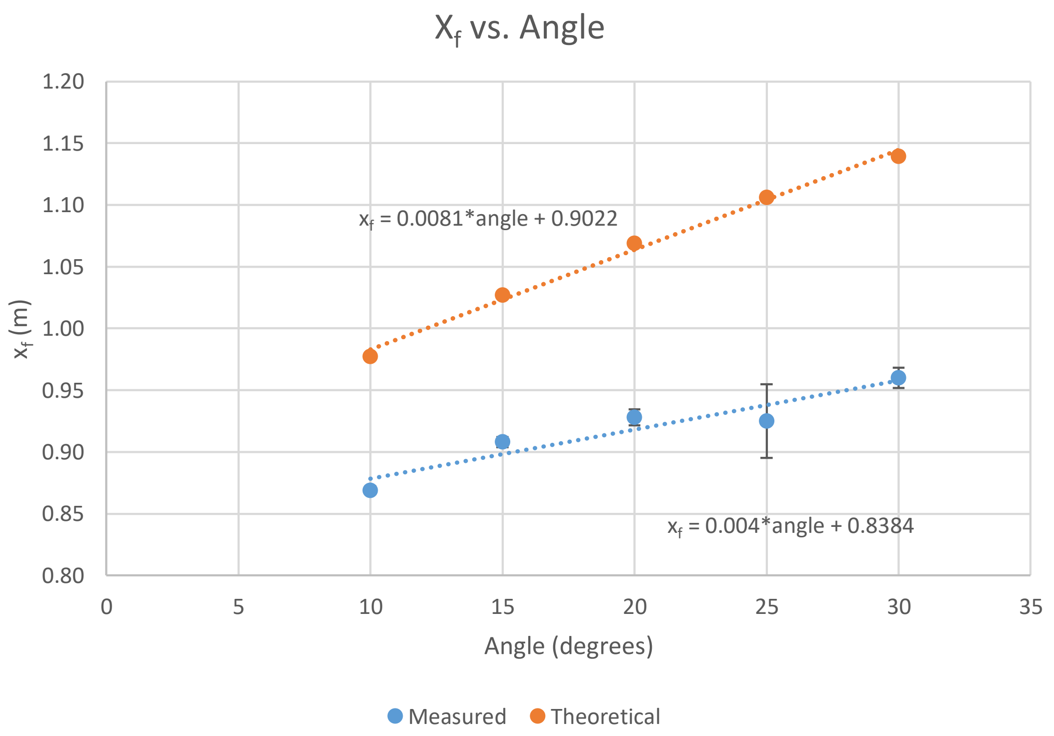


CONSTANTS AND EQUATIONS

Constants	**Equations**
$k = 58.1\ kg/s^2$ $m = 0.4688\ kg$ $Slack\ length = 0.60\ m$ $x_a = 0.00\ m$ $\Delta x_{ab} = 0.771\ m$	$\Delta x = x_f - x_i$ $PE_s = {}^1/_2\, k(\Delta x)^2$ $PE_g = mgh$ $KE = {}^1/_2\, mv^2$ ${v_f}^2 = {v_i}^2 + 2a\Delta x$ $a = g * \sin\theta$

RESULTS

	Angle (degrees)	x_{avg} (m)	STDEV (m)	%RSD of x_{avg}	x_T (m)	%Err of x	TE_i (J)	TE_f (J)	% E Change (%)
IV 1	10	0.87	0.003	0.36	0.92	13.1	0.69	0.28	59.76
IV 2	15	0.91	0.004	0.46	0.96	9.2	1.08	0.55	49.50
IV 3	20	0.93	0.006	0.68	0.99	7.2	1.46	0.72	50.89
IV 4	25	0.93	0.030	3.23	1.01	7.5	1.80	0.69	61.64
IV 5	30	0.96	0.008	0.85	1.04	4.0	2.21	1.04	52.94



DATA COLLECTION

Data Collection: Ramp angle measured with level

ANALYSIS

The data shows that displacement of a frictionless car attached to a post and on top of a ramp increases linearly with ramp angle. Thus, the higher the angle, the more the car is displaced on the ramp. Moreover, the data shows a large loss in energy, despite the fact that it should theoretically be conserved, but we did not account for small changes in sound, heat energy, etc. This also may be due to drag and air friction, and potentially some friction, although friction was assumed to negligible in this experiment because the car used has an extremely low coefficient of friction. Some sources of error include low precision and accuracy in measuring because our techniques were only vision approximates and were not comprehensive and detailed enough to achieve a higher accuracy and precision. Another source of error is that the car occasionally derailed slightly, which might have affected our measurements.

CONCLUSION

In conclusion, we found that displacement of a bungee system on a ramp increases with ramp angle. Given more time, this experiment could be improved be having a more precise and accurate way to measure x_f and different angles could be tried to corroborate our findings. Moreover, a different bungee system could be tested to see if our findings hold true for a different apparatus.

APPENDIX A: FULL DATA TABLE

	Angle (degrees)	x_1 (m)	x_2 (m)	x_3 (m)	x_4 (m)	x_5 (m)	x_6 (m)	x_7 (m)	x_8 (m)	x_9 (m)	x_{10} (m)	x_{avg} (m)	STDEV (m)	%RSD of x_{avg}	x_T (m)	%Err of x	TE_i (J)	TE_f (J)	% E Change (%)
IV 1	10	0.86	0.87	0.87	0.87	0.87	0.87	0.87	0.87	0.87	0.87	0.87	0.003	0.36	0.98	11.07	0.69	0.28	59.76
IV 2	15	0.91	0.90	0.91	0.90	0.91	0.91	0.91	0.91	0.91	0.91	0.91	0.004	0.46	1.03	11.57	1.08	0.55	49.50
IV 3	20	0.92	0.93	0.93	0.93	0.92	0.92	0.93	0.93	0.94	0.93	0.93	0.006	0.68	1.07	13.20	1.46	0.72	50.89
IV 4	25	0.93	0.93	0.85	0.91	0.91	0.95	0.94	0.94	0.94	0.95	0.93	0.030	3.23	1.11	16.38	1.80	0.69	61.64
IV 5	30	0.95	0.96	0.96	0.97	0.95	0.95	0.96	0.97	0.96	0.97	0.96	0.008	0.85	1.14	15.74	2.21	1.04	52.94

APPENDIX B: DERIVATION OF THEORETICAL EQUATION

$$v_f^2 = v_i^2 + 2a\Delta x$$

$$v_b^2 = 2 * g * \sin\theta * slack\ length$$

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$$v_b = \sqrt{2 * g * \sin\theta * slack\ length}$$

$$PE_{gb} + KE_b = PE_{gc} + PE_{sc}$$

$$mgh_i + \frac{1}{2}mv_b^2 = mgh_f + \frac{1}{2}k(\Delta x_{bc})^2$$

$$2mgh_i + mv_b^2 = 2mgh_f + k(\Delta x_{bc})^2$$

$$2mgh_i - 2mgh_f + mv_b^2 = k(\Delta x_{bc})^2$$

$$2mg(h_i - h_f) + mv_b^2 = k(\Delta x_{bc})^2$$

$$2mg * \Delta x_{bc} * \sin\theta + mv_b^2 = k(\Delta x)^2$$

$$k(\Delta x_{bc})^2 - 2mg * \sin\theta * \Delta x_{bc} - mv_b^2 = 0$$

$$\Delta x_{bc} = \frac{\sqrt{m(g^2 m (\sin\theta)^2) + kv_b^2} + mg * \sin\theta}{k}$$

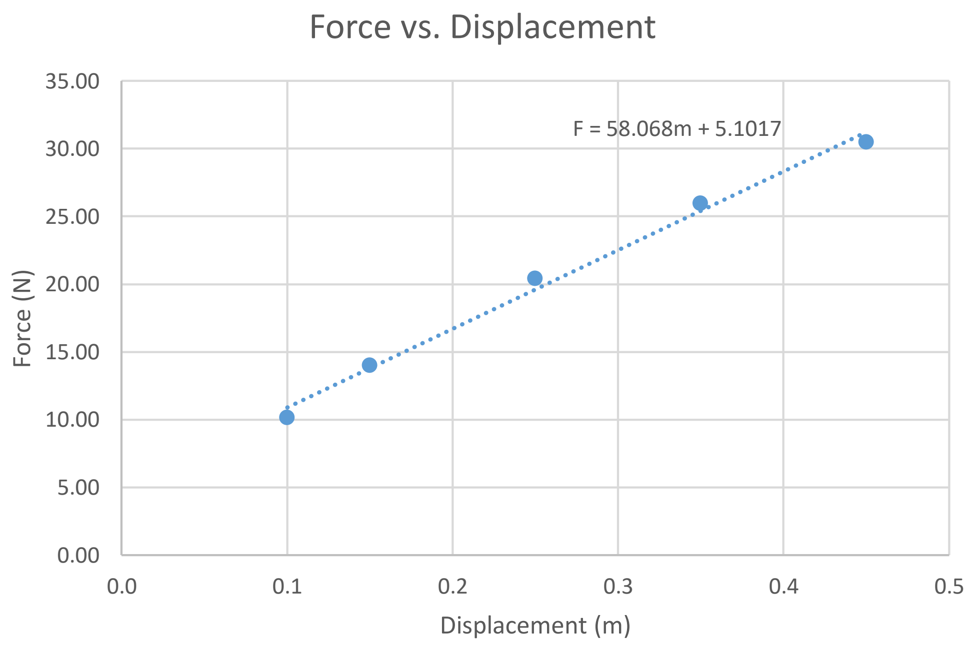
$$\Delta x_{bc} = \frac{\sqrt{m(g^2 m (\sin\theta)^2) + k(2 * g * \sin\theta * slack\ length)} + mg * \sin\theta}{k}$$

$$\Delta x_{ac} = \Delta x_{ab} + \Delta x_{bc}$$

$$\Delta x_{ac} = \frac{\sqrt{m(g^2 m (\sin\theta)^2) + k(2 * g * \sin\theta * slack\ length)} + mg * \sin\theta}{k} + \Delta x_{ab}$$

APPENDIX C: FINDING SPRING CONSTANT K

Δx (m)	F_{avgi} (N)	F_{avgf} (N)	F_{avgfi} (N)
0.10	9.99	10.30	10.15
0.15	14.15	13.81	13.98
0.25	19.86	21.00	20.43
0.45	29.49	31.46	30.48
0.35	25.89	26.04	25.97



Obtain k by taking the slope of the best fit line of Force vs. Displacement: K = 58.1 kg/s^2