Maximising horizontal flight distance of a ruler

Introduction

An object's centre of mass is a unique point where that object's mass is centred. For simple, symmetrical objects with equally distributed mass (such as a ruler), the centre of mass lies in the object's geometric centre. For more irregularly shaped objects (such as a person on a bicycle) it is more common to say the “person and bikes centre of gravity," which refers to a point on an object which is identified by averaging together all the gravitational forces acting on that object. Earth's gravity produces a relatively uniform downward pull on small objects near its surface. If there's more mass in one region of an object than another (say, a person on top of a bike rather than the bike's wheels), then gravity applies more force to that region. We can apply this to children sitting on a seesaw. You can create a simple mechanical system consisting of a lever (the seesaw's plank), a fulcrum (the point about which the plank can tilt) and a couple of masses (the children). If the two children weigh the same, the system's centre of mass is located in centre of the seesaw's plank and directly above the fulcrum. Put a heavier child on one end of the seesaw, and you've shifted the system's centre of mass away from the fulcrum. The greater torque (or force) that gravity applies to the more massive (heavier) side of the system pulls the larger child to the ground while lifting the smaller child into the air. This concept can be then applied to a lightweight tipcat (lighter child), ruler on a table (seesaw and changing fulcrum) and a mass which is dropped from a fixed height (heavy child). If there is a large difference between the two forces, the heavier object being dropped can in turn launch the lighter object into the air and across a short distance.

Aim

To measure the horizontal flight distance of a ruler hanging over the edge of table when a force is applied to the ruler.

Hypothesis (Situation 1)

When the ruler has a 10 cm (0.1 m) overhang over the edge of the table, it will show the longest horizontal flight distance when a force is applied in comparison to the other lengths of overhang of the ruler.

Hypothesis (Situation 2)

When the mass of 50 g is dropped 10 cm (0.1 m) from the edge of the table onto the ruler, it will show the longest horizontal flight distance in comparison to the other places where on the ruler which the force is applied to.

Variables

Situation 1

- Independent—The changed length of the overhang of the ruler on the table (m)
- Dependent—Horizontal flight distance of ruler (m)
- Controlled—Type of ruler, Forced/Mass used, Fixed height from where mass is dropped

Situation 2

- Independent—The position of force applied on a ruler hanging over the table of fixed length (m)
- Dependent— Horizontal flight distance of ruler (m)
- Controlled—Type of ruler, Force/Mass used, Fixed height from where mass is dropped, Fixed fulcrum position

Methodology

Materials

- 30 cm Wooden Ruler
- Table
- 50 g mass

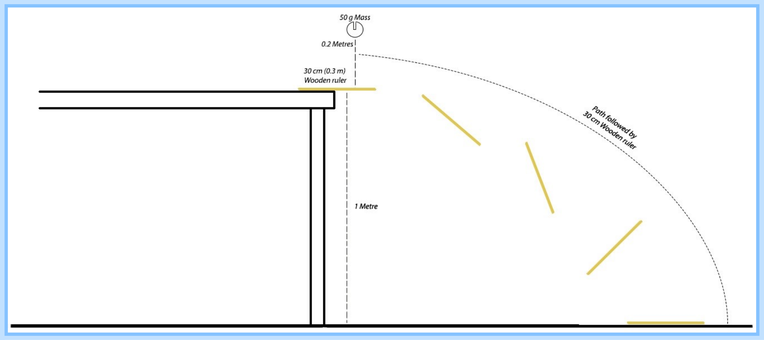
Method

Situation 1

1) Place ruler on edged of table so that there is a 6 cm overhang over the edge of the table.
2) Drop a 50 g mass from a fixed height above the ruler on the furthest part of the ruler away from the table on the section of the overhang.
3) Watch the ruler fly and measure the horizontal distance of flight (starting position to first place on ground it touched). Record results.
4) Repeat steps 1-3 three more times using the same distance to get repeated results, then take the average of the results and record.
5) Repeat steps 1-4 but for overhangs of 8, 10, 12 and 14 cm.

Situation 2

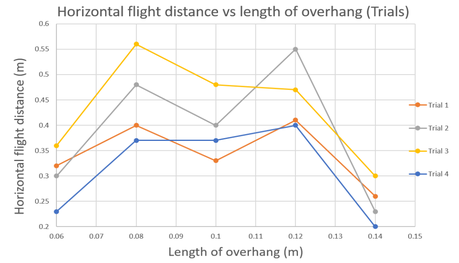
1) Place ruler on edged of table so that there is a 15 cm overhang over the edge of the table.
2) Drop a 50 g mass from a fixed height above the ruler on the section of the overhang 2 cm away from the edge of the table.
3) Watch the ruler fly and measure the horizontal distance of flight (starting position to first place on ground it touched). Record results.
4) Repeat steps 1-3 three more times using the same place where mass was dropped to get repeated results, then take the average of the results and record.
5) Repeat steps 1-4 but for 4, 6, 8, 10, 12 and 14 cm from the edge of the table along the overhang where the mass is dropped onto the ruler.

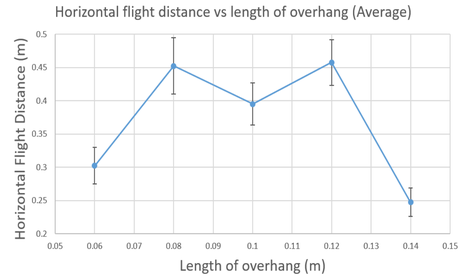


Results

Situation 1: Changing the fulcrum

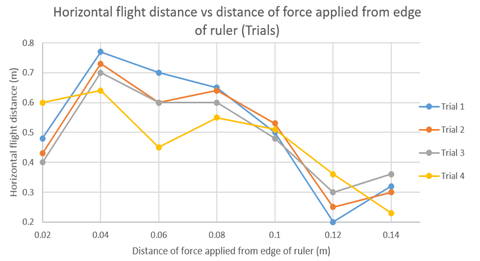
Length of Overhang (m)	Trial 1	Trial 2	Trial 3	Trial 4	Average (m)	Standard Deviation	Standard Error
0.06	0.32	0.3	0.36	0.23	0.3025	0.05	0.03
0.08	0.4	0.48	0.56	0.37	0.4525	0.09	0.04
0.1	0.33	0.4	0.48	0.37	0.395	0.06	0.03
0.12	0.41	0.55	0.47	0.4	0.4575	0.07	0.03
0.14	0.26	0.23	0.3	0.2	0.2475	0.04	0.02

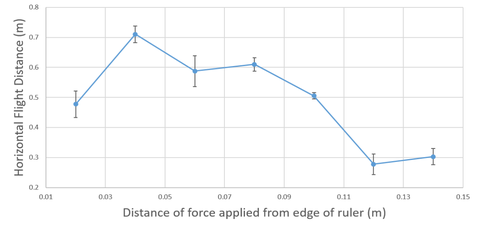




Situation 2: Fixed force but place where force occurs changes

Distance of force applied from edge of ruler (m)	Trial 1	Trial 2	Trial 3	Trial 4	Average (m)	Standard Deviation	Standard Error
0.02	0.48	0.43	0.4	0.6	0.4775	0.09	0.04
0.04	0.77	0.73	0.7	0.64	0.71	0.05	0.03
0.06	0.7	0.6	0.6	0.45	0.5875	0.1	0.05
0.08	0.65	0.64	0.6	0.55	0.61	0.05	0.02
0.1	0.5	0.53	0.48	0.51	0.505	0.02	0.01
0.12	0.2	0.25	0.3	0.36	0.2775	0.07	0.03
0.14	0.32	0.3	0.36	0.23	0.3025	0.05	0.03





Discussion

Some of the safety precautions taken during the running of the experiment were:

- Making sure no one was standing in front of ruler when it was launched.
- Having feet away from underneath the ruler so that the mass didn’t land on someone’s foot.
- Carefully dropping mass so that it does not flip the ruler and making it launch in the wrong directions

Four repeats were done in each changing of the independent variable in both situations. In situation 1, twenty repeats were done while in situation 2, twenty-eight repeats were done making a total of forty-eight repeats. More accurate results would have been found if ten repeats were done instead of four for each variable change but due to time constraints and limitations it would have totalled one-hundred and twenty repeats instead of forty-eight. More tests would have helped minimise error in the overall average of each test and also help minimise the standard error of each test so that there was only minute differences between a perfect test. Results showed slight inaccuracies and some trials varied more than others due to the way the mass was dropped and positioning of the mass over the ruler being changed slightly when repeating tests. In the two situations the aspect that could have been most improved was making a mechanical arm which held the mass at a fixed height so that every time it was dropped it was almost always exactly dropped from the same height as the previous trials. The constraint which prevented us from doing this was time and how long it would actually take to build something like that which could then be easily reset after each trial. Other aspects of the tipcat and ruler experiment could have been explored but these two situations proved to be most interesting in relation to constraints. Other aspects included:

- Changing the height at which the mass was dropped from could have been explored to see the relation between force, mass and acceleration due to gravity. This would have been much harder to achieve as getting exact heights would be difficult due to slight movements in the arm and if the person undertaking the experiment got tired. Safety precautions in this other aspect would have much more difficult as you would need to get onto a table or ladder to move the height at which mass is dropped.
- Changing the sharpness of the edge of the table. This would have been to see if there were any effects in association with the shape of the table edge itself. It might have shown differences between a sharp table edge and a curved table edge and if it showed any change in the horizontal kick of the tipcat.
- Dropping the mass in a horizontal flat position instead of vertically. In the experiment we had dropped it vertically while if we had dropped it horizontally there might have been more area of the mass hitting more surface area of the ruler causing a difference in the horizontal launch distances.

It was found in situation 1 that the maximum average distance that the ruler flew was 0.4575 m when the ruler had a 0.12 m overhang. In situation 2 it was found that the maximum average distance of flight was 0.5875 m when the mass was dropped 0.06 m from the edge of the table. Angular momentum of an object is formed by the product of its moment of inertia about its axis and the angular velocity. In the case of this ruler, it is much harder to define and calculate because of the unevenness of the rulers radius. Every little infinitesimal section of the ruler has its own angular velocity and is at a different radius from the centre of the object. The speed at the edge of the ruler would be different from the speed of the section of the ruler closer to its centre. When the mass hit the ruler, the ruler it self has not only gravitational potential energy but it also has some elastic energy. The combination of the energy being stored will transfer to kinetic energy as it travels in the air. After the mass hit the ruler, it exerted a force on the ruler which therefore broke the balance and created a torque. The ruler then flies and begins spinning at the same time because of the torque effect. The torque effect is a result of Newton’s Third Law of Motion that “for every action, there is an equal and opposite reaction.” This also means that angular momentum is proportional the moment of inertia and angular speed. Angular momentum can be calculated with the equation L=Iw, where L is the angular momentum, I is the moment of inertia and w (omega) is the angular speed. It is hard to go through the whole formula in examples as it is very complicated and much of the information and equations have not been learnt yet, which is another area of improvement for future experiments undertaken like this.

Conclusion

The hypothesis for situation 1 “when the ruler has a 10 cm (0.1 m) overhang over the edge of the table, it will show the longest horizontal flight distance when a force is applied in comparison to the other lengths of overhang of the ruler” was not supported by the results and trials taken. It was found to be at a overhang of 0.12 m that there was the longest flight distance. The hypothesis for situation 2 “when the mass of 50 g is dropped 10 cm (0.1 m) from the edge of the table onto the ruler, it will show the longest horizontal flight distance in comparison to the other places where on the ruler which the force is applied to” was not supported by the results and trials taken. It was found to be the longest flight distance when the force was applied at 0.06 m. To summarise the tests, it was found on average the longest horizontal flight distance of the ruler was when the place on the ruler where the force was applied was changed to 0.06 m from the edge of the table. This showed optimal conditions through this experiment to show maximal flight distance of the ruler.

Acknowledgements

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References

https://en.wikipedia.org/wiki/Rotation_around_a_fixed_axis

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