# Pendulum Art: A Swinging Good Time

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## Physics Background and Objectives

Different physics topics are applicable to a pendulum art piece: Newton's laws of motion, inertia, simple harmonic motion, uniform circular motion.

**Newton's 1st Law:** The 1st law states that if a body is at rest or moving at a constant speed, it will remain at rest or keep moving at constant speed unless it is acted upon by a force.[1] This is why during our experiment we will tap our bucket after a certain number of revolutions to change the projection pattern on the canvas.

**Newton's 3rd Law:** The 3rd law states that when two bodies interact, they apply forces to one another that are equal in magnitude and opposite in direction.[1] Simplified this means that for every action, there is an equal and opposite reaction. In our pendulum, the swinging motion is the result of the 3rd law and the force is decreased due to air resistance/drag.

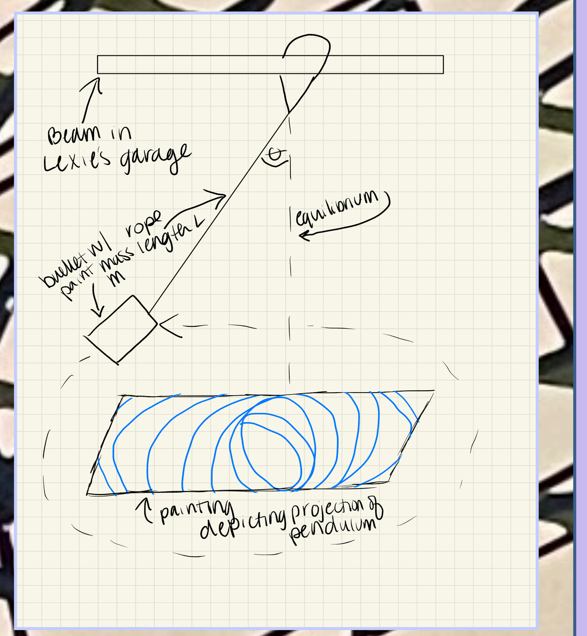
**Inertia:** Once the pendulum is released, the force of its inertia will cause the paint to flow back and forth across the canvas creating a natural spiral. As the paint is released and the mass of the pendulum changes, the spirals will become smaller and smaller.[2] Inertia is calculated with: $I = \sum_i m_i r_i^2 = \int r^2 dm$

**Simple Harmonic Motion:** A point P moving on a circular path with a constant angular velocity (ω) is undergoing uniform circular motion. Its projection on the x-axis undergoes simple harmonic motion.[3] On our pendulum, this projection can be compared with the pattern from the horizontal motion of the bucket of paint moving across the canvas.

**Uniform Circular Motion:** Simple harmonic motion is similar to circular motion. You can describe an object moving in a circular path by determining the angle and radius it takes in its corresponding circular path.[4] For our calculations, we will be looking at the period, which is the time for an object to complete one full revolution with the equation: $T = 2\pi\sqrt{\frac{L}{g}}$.[5] Angular velocity is calculated with: $\omega = \sqrt{\frac{g}{L}}$.[5]

Gravity is calculated with: $g = \omega^2 L$.[6]

We will be testing changing the mass of the bucket in the pendulum, the length of the rope, and the angle that the bucket is released from. Each team member predicted which change will have the most significant outcome. Bee predicted angle, Marie predicted length, and Lexie predicted mass. The calculations are period, angular velocity, gravity, and percent error for our actual data versus theoretical values.




## Building Process

A rope was attached to a beam in Lexie's garage, and it was measured to 90 inches total with 2 yardsticks and a marker, and the rope had a knot tied at the 77 inch mark. The angles were measured from the beam with a protractor and marked on the tarp with angle markers. Holes were drilled into the bottom of the buckets with a power drill and a medium sized drill bit, and then the holes were stuffed with cotton balls and sealed over with tape. The colors used were Black Sapphire (purple), Nocturne Blue (blue), and Trailing Vine (green).

## Analysis

### Mass Trials

| | BS | NB | TV |
|---|---|---|---|
| Mass | 2.81 kg | 1.54 kg | 1.18 kg |
| Angle | 30º | 30º | 30º |
| Length | 1.96 m | 1.96 m | 1.96 m |
| Time | 60s | 60s | 60s |
| Bumps | 1 @ 10 revs | 1 @ 10 revs | 1 @ 10 revs Stop at 18 |

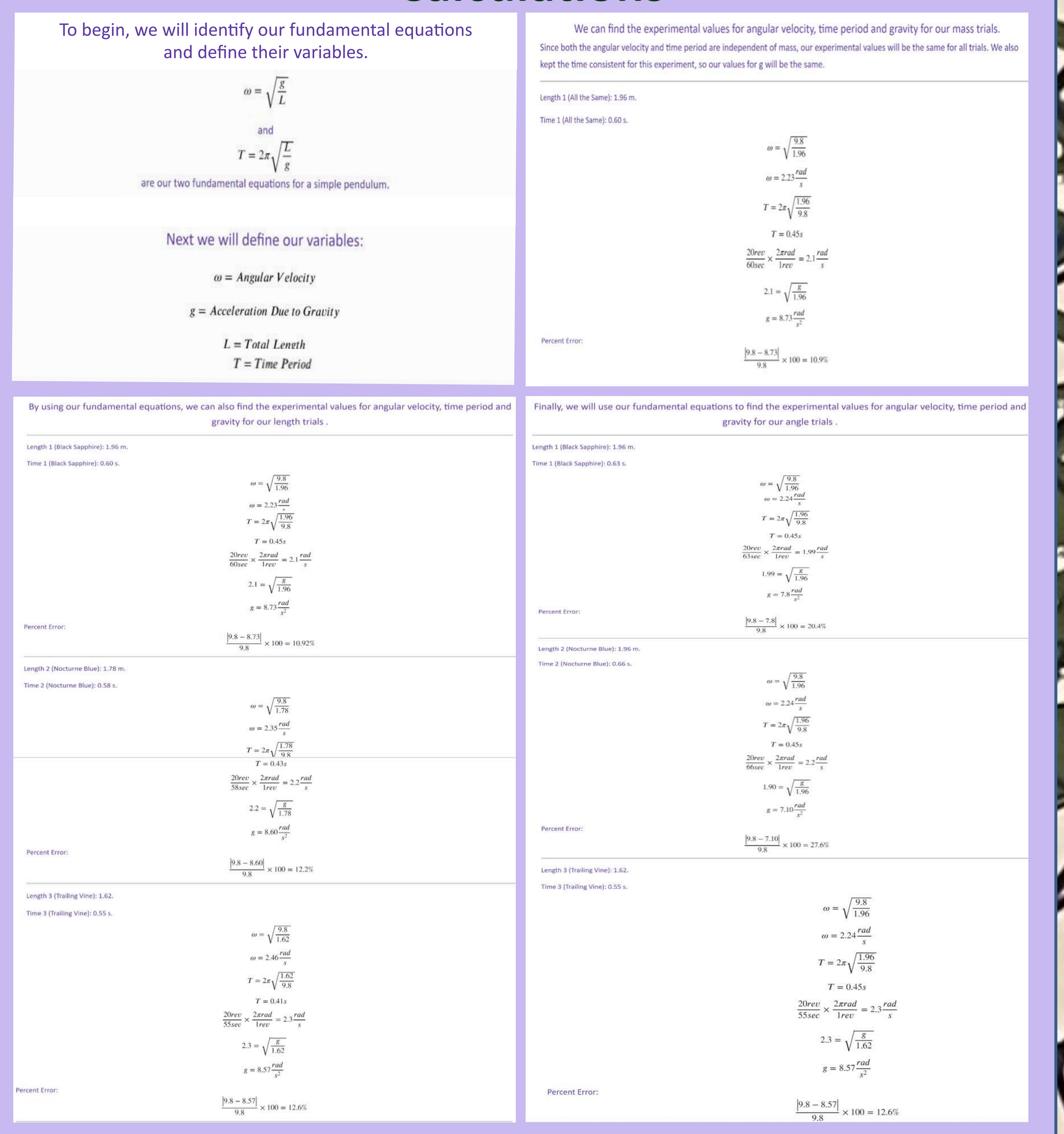
### Length Trials

| | BS | NB | TV |
|---|---|---|---|
| Mass | 1.09 kg | 1.09 kg | 1.09 kg |
| Angle | 30º | 30º | 30º |
| Length | 1.96 m | 1.78 m | 1.65 m |
| Time | 60s | 58s | 55s |
| Bumps | 1st @ 10 revs Stop at 15 | 1st @ 10 revs 2nd @ 13 revs | 1st @ 13 revs tape error |

### Angle Trials

| | Black Sapphire | Nocturne Blue | Trailing Vine |
|---|---|---|---|
| Mass | 2.18 kg | 2.18 kg | 2.18 kg |
| Angle | 60º | 45º | 30º |
| Length | 1.96 m | 1.96 m | 1.96 m |
| Time | 63s | 66s | 55s |
| Bumps | No bumps | 1st @ 8 revs | 1st @ 8 revs 2nd @ 12 revs |

### Calculations




From looking at our final paintings, Bee's hypothesis that changing the angle had the biggest impact on the final painting was correct. We saw the most changes in the pendulum projection with the angle changes between 30º, 45º, and 60º. Marie's hypothesis of length produced the smallest revolutions and the bucket had to be stopped for two runs before 20 revolutions. Lexie's hypothesis of mass had the thickest flows of paint coming out of the bucket. This was especially true for the black sapphire run, because the increase in mass hugely increased the flow of the paint.

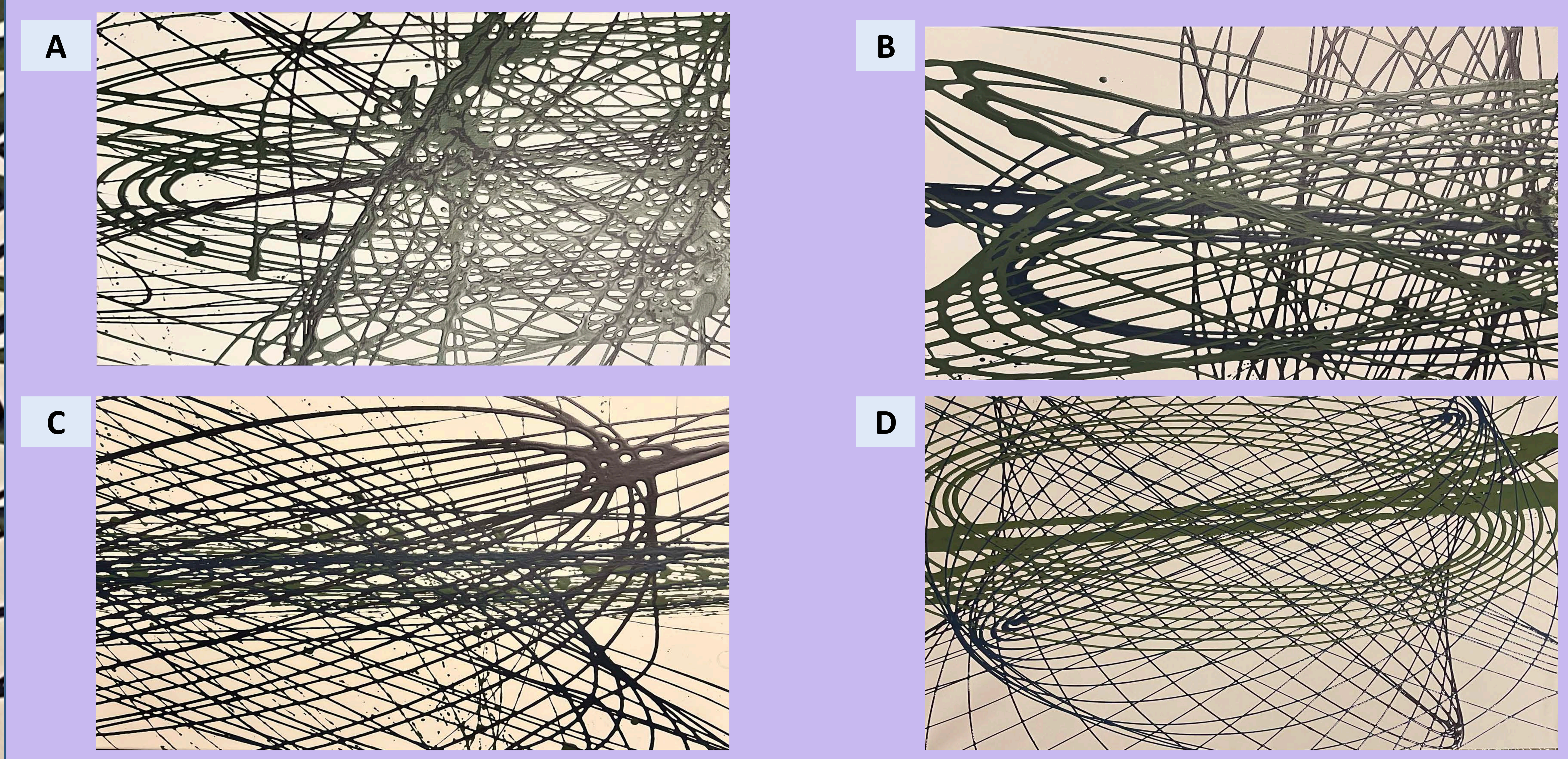



**Figure A: Test Canvas, Figure B: Mass Trials, Figure C: Length Trials, Figure D: Angle Trials. The colors used were Black Sapphire (purple), Nocturne Blue (blue), and Trailing Vine (green)**

## Conclusion

If we were to run the experiment again:

✳ We would take pictures between each run like we did with the Angle Trials.

✳ We would also pick more dramatically different colors so that there was more contrast between each run.

✳ We would use the large canvas size or use butcher paper for larger paintings.

This was a fun experiment and we each ended up with an amazing painting from our trials

## Testing Process

Before each trial run, the bucket was weighed with the paint in it on the scale. The bucket was then tied to the rope to the appropriate length for the trial. Then the bucket was pulled back to the angle mark. Before the bucket was released, the tape and cotton were removed and the paint flow started out of the hole. After a certain number of revolutions, the bucket was tapped to change the oscillation pattern. Each trial was timed, the revolutions were counted, and the bucket was stopped at 20 revolutions.

## Errors

✳ Wind coming in the garage through a gap in the bottom of the door.

✳ The hole in the bottom of the bucket was off center, and the trailing vine bucket was drilled twice because the first hole wasn't large enough.

✳ During the Mass Trials the rope on the beam shifted and had to be moved back to the starting point.

✳ Mass Errors:

- ✳ There was paint on the scale and exterior of the buckets that affected the mass readings.
- ✳ The tape and cotton ball were on the side of the bucket for some runs, but not include in the mass reading.

✳ As the bucket slowed, the paint lines got closer together, because the inertia decreased. This caused some trials to be stopped before 20 revolutions.

✳ The last length trial run had a tape error where the cotton ball and tape were not fully removed, causing a thinner stream and dotting

✳ Precision Errors:

- ✳ The scale went only to the tenths place and the protractor was measurable to one degree.

## References

1) Britannica, T. Editors of Encyclopaedia (2021, July 23). Newton's laws of motion. Encyclopedia Britannica. https://www.britannica.com/science/Newtons-laws-of-motion

2) Neuberger Museum of Art Education Team. (2022). Let's Create A Pendulum Painting. Retrieved April 25, 2022, from https://www.purchase.edu/live/files/3418-project-create-a-pendulum-painting

3) Physics & Astronomy Department at Western Washington University. (2022). *Simple harmonic and uniform circular motion - pendulum*. Simple Harmonic and Uniform Circular Motion - Pendulum. Retrieved April 20, 2022, from https://physics.wwu.edu/simple-harmonic-and-uniform-circular-motion-pendulum#:~:text=A%20point%20P%20moving%20on,horizontal%20motion%20of%20a%20pendulum.

4) Ather, S. H. (2020, December 28). Laws of Pendulum Motion. Retrieved May 1, 2022, from https://sciencing.com/laws-pendulum-motion-8614422.html

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6) Libretexts. (2022, February 20). *15.5: Pendulums*. Chapter 15. Retrieved May 2, 2022, from https://phys.libretexts.org/Bookshelves/University_Physics/Book%3A_University_Physics_(OpenStax)/Book%3A_University_Physics_I_-_Mechanics_Sound_Oscillations_and_Waves_(OpenStax)/15%3A_Oscillations/15.05%3A_Pendulums