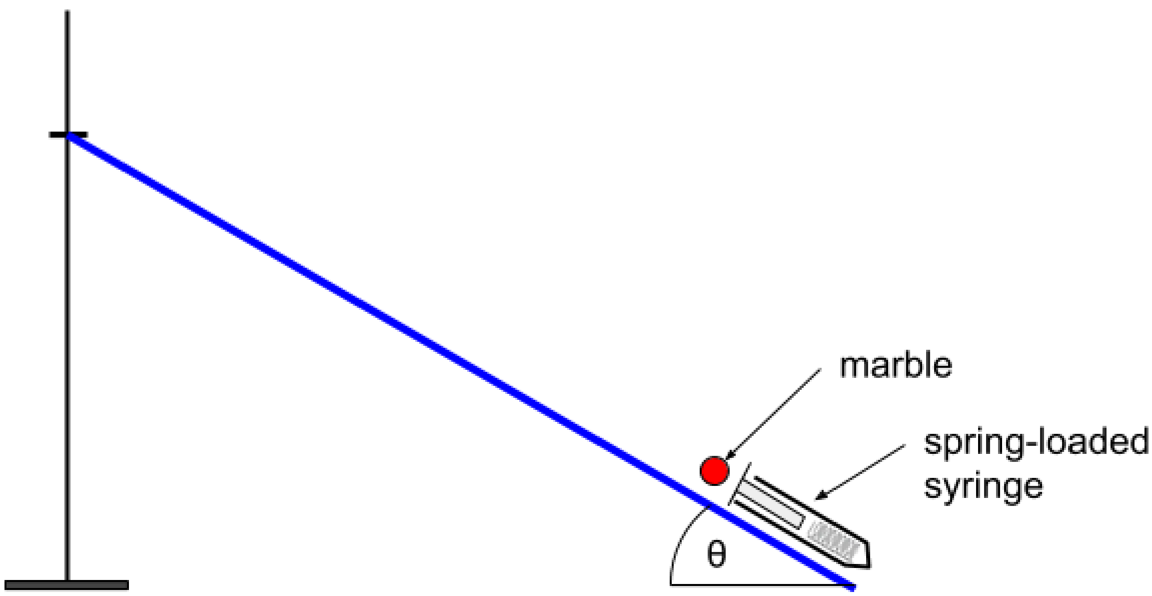
# Springs and Marbles

*Investigation on how the angle of a ramp alters the distance travelled by the marble up the ramp:*

*Diagram of the apparatus is below:*

## Background knowledge and useful equations:

Diagram by Timothy Langer




$W = F d \cos\theta$

$\therefore F = \mu N$

$N = mg \cos\theta$

$KE = \frac{1}{2}mv^2$

## Hypothesis

1. As the angle of the ramp increases the distance travelled by the marble will decrease.
2. The vertical distance travelled by the marble would stay the same. As the ramp's friction would have a negligible on the marble's speed.

## Predictions

1. The distance travelled along the ramp will decrease linearly as the angle $\theta$ increases.
2. The vertical distance travelled by the marble would stay the same provided the experiment was performed on a frictionless ramp.

## Method

Keeping the marble size, density and frictional coefficient the same, footage of the marble travelling up and down the ramp was recorded using a high-speed video camera. This was played back 8 times slower than real time and the (diagonal) distances travelled up the ramp were calculated using trigonometry. Three tests were run for each angle, allowing us to discount any anomalies and find a mean value for each angle. This, in turn, allowed us to calculate the average vertical distance travelled (using the sine rule).

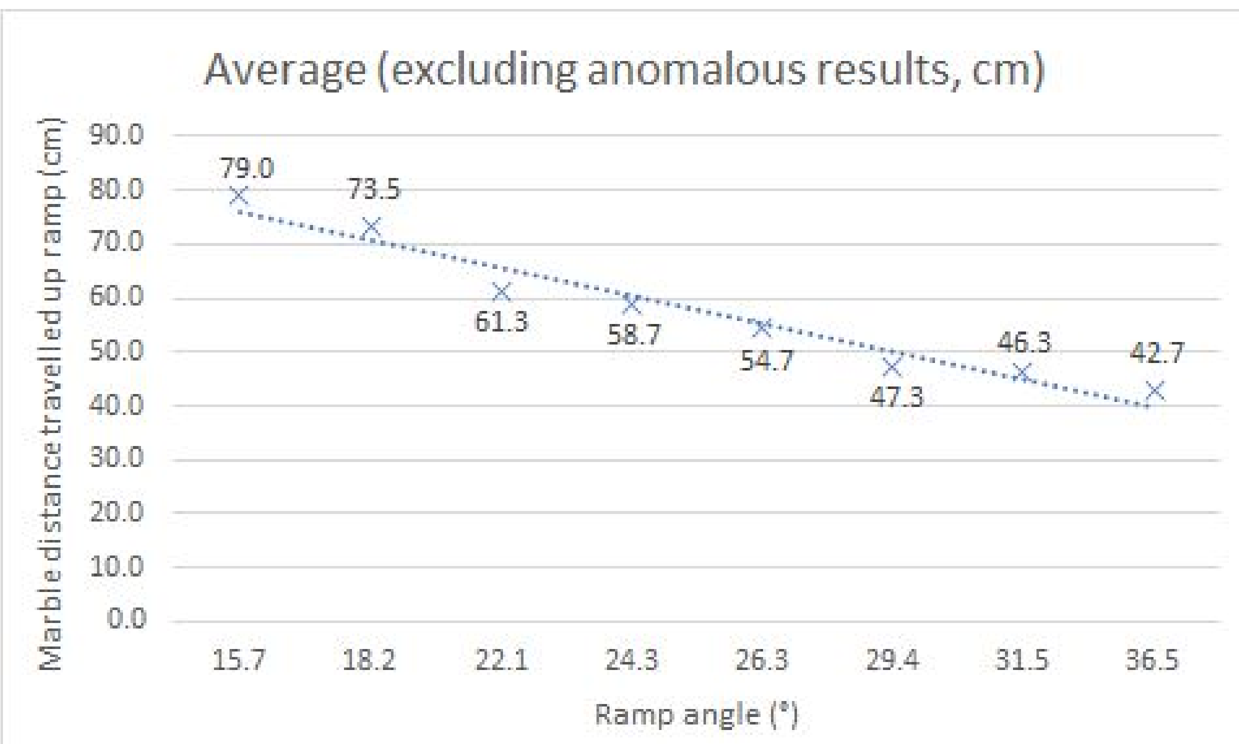
For an example video (1st test at 24.3°), go to https://zeevox.net/marbles

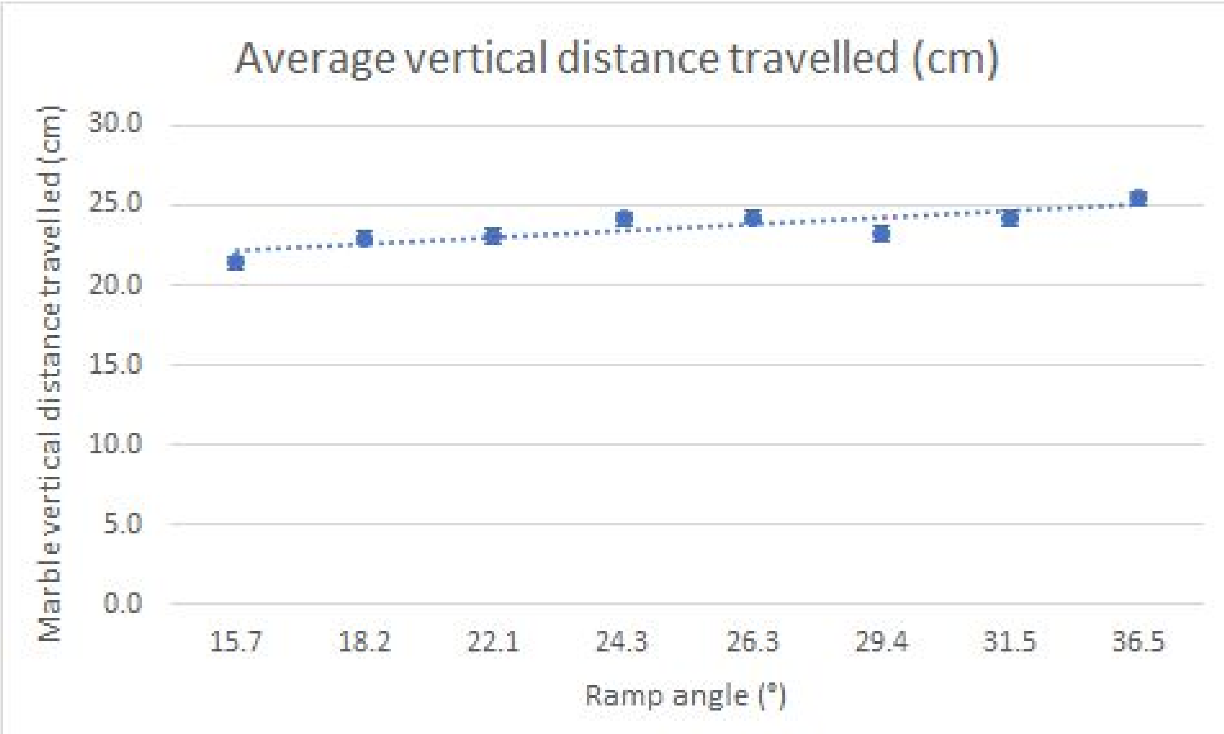
## Data

(Anomalous results highlighted orange)

| Ramp angle (°) | Distance travelled by marble up the ramp (cm) | | | Average distance travelled up the ramp (excluding anomalous results) (cm) | Average vertical distance travelled (cm) |
|---|---|---|---|---|---|
| 15.7 | 78 | 80 | 56 | 79.0 | 21.4 |
| 18.2 | 74 | 73 | 54 | 73.5 | 23.0 |
| 22.1 | 63 | 59 | 62 | 61.3 | 23.1 |
| 24.3 | 57 | 58 | 61 | 58.7 | 24.2 |
| 26.3 | 54 | 55 | 55 | 54.7 | 24.2 |
| 29.4 | 50 | 47 | 45 | 47.3 | 23.2 |
| 31.5 | 45 | 49 | 45 | 46.3 | 24.2 |
| 36.5 | 43 | 43 | 41 | 42.7 | 25.4 |

## Graphs






## Results

As the angle $\theta$ increased the distance travelled up the ramp decreased linearly, however the average vertical distance travelled only increased slightly. This is because as the distance travelled along the ramp (at a smaller angle) increased there was a longer distance over which the some of the marble's kinetic energy would dissipate due to the ramp's friction. This results also affirms to some extent our third hypothesis (that

## Conclusion

Our data proved supports the first part of our hypothesis. As the angle of the ramp was increased, the distance travelled along the ramp decreased linearly. The average proportion was calculated to be -1.75 cm/degree increased. When launched (excluding the margin of error provided by human variation) all marbles had the same amount of total energy. As they roll up the ramp, the majority of this energy is converted into gravitational potential energy, however, some will turn into rotational kinetic energy due to the friction of the ramp, which turned out to not have been negligible. On a frictionless ramp (which would have been an ideal test scenario), this would not happen and all energy would convert into GPE. Thus, each would achieve the same vertical height. Further tests could be done with ramps varying in frictional coefficients to further test our second hypothesis.

## References


1. Kurtus, R. (2016). Standard Friction Equation by Ron Kurtus - Physics Lessons: School for Champions. [online] School-for-champions.com. Available at: https://www.school-for-champions.com/science/friction_equation.htm [Accessed 27 Mar. 2019].

2. Richmond, M. (2014). Gravitational Potential Energy, and Conservation of Energy. [online] Spiff.rit.edu. Available at: http://spiff.rit.edu/classes/phys211/lectures/gpe/gpe_all.html [Accessed 27 Mar. 2019].

3. Julius O. Smith III, W3K Publishing, 2010, Center for Computer Research in Music and Acoustics (CCRMA), Stanford University https://ccrma.stanford.edu/~jos/pasp/Newton_s_Three_Laws_Motion.html