# How does changing the drop height affect the Coefficient of Restitution of a ball?

## Aim

To identify the coefficient of restitution ($C_r$) of a basketball by changing the initial drop height and identifying the resulting rebound height.

## Hypothesis

If the relationship between the drop height of the object and the coefficient of restitution is the square root of an inverse then as the drop height increases, $C_r$ should decrease.

## Background Physics

The coefficient of restitution is a measure of how elastic a collision is. The coefficient of restitution is given by square root of kinetic energy after impact over the kinetic energy before impact or,

$$Cr = \sqrt{\frac{\frac{1}{2}mv^2}{\frac{1}{2}mu^2}} = \sqrt{\frac{v^2}{u^2}} = \frac{v}{u}$$

The coefficient can also be given the square root of the potential energy at bounce height over the potential energy at drop height,

$$Cr = \sqrt{\frac{mgh}{mgH}} = \sqrt{\frac{h}{H}}$$

Coefficient of restitution is limited to a value of 0 to 1, where 0 represents a perfectly inelastic collision and 1 is a perfectly elastic collision. When an elastic collision occurs, no energy is lost to the surroundings. In this experiment, a perfectly elastic collision is not expected as energy will be lost either in the form of rotational kinetic energy or thermal energy. As the velocity of the ball increases it will be subject to a greater air resistance which will affect its path of motion. As the ball hits the ground it loses its shape, how well the ball gains energy from this deformation will affect the coefficient of restitution.

| Dependent Variable | Independent Variable | Control Variable |
|---|---|---|
| • Bounce height of the ball | • Initial drop height of the ball | • Air pressure and type of ball<br>• Surface of impact against ball |

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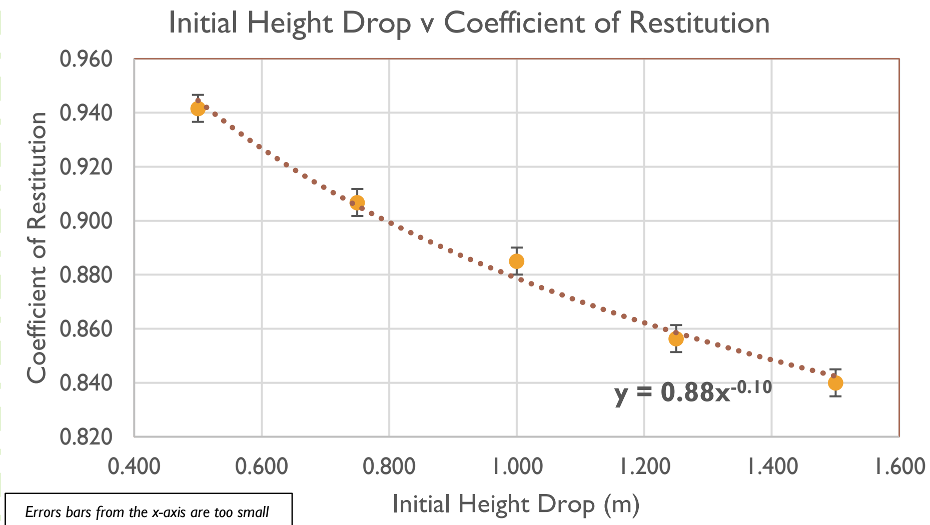


*Errors bars from the x-axis are too small to see due to the low tolerance value*

## Methodology

1. Set up measuring tape along wall in a straight line.v
2. Tape the top and bottom of the measuring tape to ensure it does not move.
3. Measuring from the ground, mark intervals at 0.50, 0.75, 1.00, 1.25 and 1.50 metres.
4. Starting from lowest interval, set up camera just belong the mark to reduce parallax error of recorded evidence.
5. Using the same ball for all trials, drop the ball with the bottom of the ball at the marked interval whilst camera is recording. Repeat these three times for each interval.
6. When dropping the ball make sure to have two hands on each side of the ball and ensure to let go of the ball simultaneously.
7. When changing to the next interval ensure camera is also being moved to a higher level to be kept at level with the ball throughout the experiment.
8. Record data in logbook and use camera footage to analyse height achieved

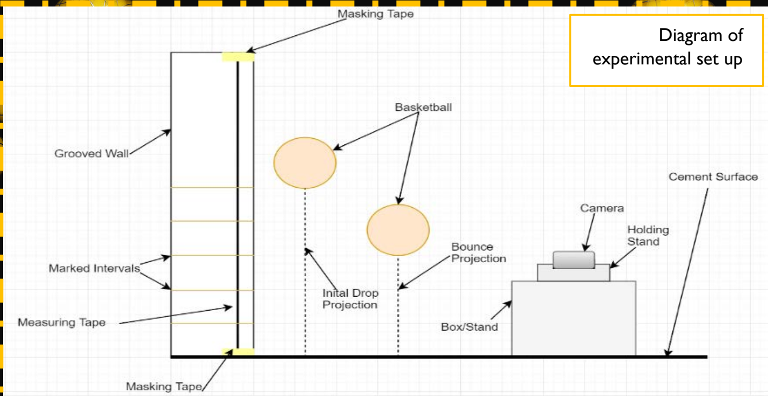


Diagram of experimental set up

## Discussion

The results of the investigation show that the relationship between the changing drop height and the resultant coefficient of restitution is given by the function $y=0.88x^{-0.1}$ where y represents the Cr value and x is the drop height value. An appropriate tolerance value was calculated for such results and is indicated by the error bars on the graph. The produced trendline fits within such tolerance meaning the data is accurate assuming the produced trendline is an accurate approximation of the resulting data. The relationship is classified as an inverse power which supports the which supports the hypothesis statement as it was predicted that as H increases, Cr will decrease. From the graph produced all data falls between a range of 0.84 to 0.94. This is expected as a basketball is designed to have a coefficient value between 0.82 and 0.88 when dropped from a height of 1.8m. The expected value for the relationship function was different to the obtained result but not completely inaccurate. The expected function held a power value of 0.5 due to the formula of Cr having a square-root. Whilst the experimental value was not exactly accurate it still achieved roughly the same formula.

The results produced and trends that are present can be explained using relevant physics concepts. As the ball reforms, it gains kinetic energy from elastic potential energy which causes the action of the ball to bounce against the ground. As the drop height increases, the kinetic energy of the ball before it hits the ground is larger as velocity has increased. Due to this increase in kinetic energy the rebound height does increase but the ratio of rebound height to drop height decreases. Due to the increase in air resistance as velocity increases the ball is subject to a greater amount of force against its projected path and thus causes such decrease in its ratio.

Some outliers were produced that can be recognised by an amount greater than 0.5 from other sets of data. These outliers could have been due to random errors including loss of energy through kinetic or thermal energy. These random errors can be reduced by averaging the completed trials which was completed in this experiment. Systematic errors were produced from the measuring tape as the tape was found to not be accurately straight which was occurrent throughout the tests. To fix this error a straight reference is required which can be assembled using long rulers and a protractor. The accuracy of the experiment was limited due to the equipment used. Some constant variables such as the dropping of the ball were not constant through the experiment as it was dropped from outside the accepted tolerance. This can error can be adjusted with a controlled ball release system to reduce the variation in direction and distance.

## Conclusion

From the data produced, the expected relationship was produced as stated from the hypothesis. Due to the equipment used many errors occurred within the experiment which affected the experimental accuracy and precision. Through this experiment it is justifiably known that the relationship between drop height and coefficient of restitution is inversely to a power of value, $Cr = 0.88H^{-0.1}$.