How does the energy that a basketball loses after bouncing on the rim depend on the location at which the basketball is dropped?

IBDP SL Physics IA - Adam Sadek

Background:

In the sport of basketball, arguably the most important skill is being a good shooter. However, there come times where a basketball player must rely on "the kindness of the rim." The rim can offer a shooter a "friendly bounce," which means that the ball bounces high off the rim initially after the shot and then falls through the net (Larry Brown, Larrybrownsports). The inspiration for this investigation comes from a recent event in the 2019 NBA playoffs, during game 7 (the elimination game) in the Eastern Conference semifinals, the Toronto Raptors vs the Philadelphia 76ers. The game was tied at 90-90, with only a few seconds left in the game. Kawhi Leonard on the Raptors threw up a shot with 0.3 seconds left on the clock from the three point line that would bounce high off the rim, and then continuously dance around the rim, until inevitably falling through the net, sending the 76ers home. The Raptors would advance to eventually win the NBA finals. In figure 1, it is clear how high the ball bounces after hitting the rim (Barry Petchesky, deadspin). This picture was taken after the ball had already initially made contact with the rim, and it can be seen that the ball peaks even over the backboard.

Figure 1: Basketball peaking over rim after Kawhi Leonard's shot (Image from deadspin.com)

A basketball rim is bolted into the backboard on the inside. This area where the rim meets the backboard is known as the "heel" of the rim. On the sides and outside of the rim it is suspended in air. This difference may mean that there is a spot on the rim that will result in a greater bounce, and therefore a shot that is more likely to go in. According to Newton's first law, an object at rest remains at rest, or if in motion, remains in motion at a constant velocity unless acted on by a net external force (openstax, cnx.org). Thus, when the basketball is dropped above the rim, it naturally wants to keep moving downwards, until it makes contact with the rim. As the ball drops, the ball's potential energy changes to kinetic (Smithsonian National Air and Space Museum, howthingsfly). However, as previously mentioned, the rim is not completely uniform all around, so when the ball makes contact with the rim, the amount of energy that the rim absorbs at a particular location will differ. A harder part of the rim will absorb less energy, and the less energy the rim absorbs, the more that remains in the ball for it to bounce (Science Buddies, ScientificAmerican). It may also be that the rim has similar mechanics to that of a diving board, in which the edge of the board provides the greatest bounce because it launches the diver upwards.

This investigation involves momentum and impulse, because as the ball falls towards the rim, it has a velocity, and momentum is characterized as the mass of the object multiplied by its velocity (the Physics Classroom, Momentum). However, the ball will lose momentum when it hits the rim because it transfers some of its energy elsewhere. The outermost part of the rim, opposite the backboard, is not bolted anywhere, so it has some give (the ability to have momentum), unlike the heel of the rim, closest to the backboard, which is bolted and will therefore have no give. The amount of give on the sides will be slightly less than on the outermost side of the rim. The amount of give is important because it means that when the ball makes contact with the rim, it may be forced to directly change its motion, or slow down first and then change its motion, depending on where on the rim the ball hits. When the rim is hit at a point that isn't bolted down, the rim will temporarily deform, as the normal force will not be enough for the force of the ball. Because of this, the rim will want to spring back into its initial position. This is called the restoring force. This may result in a greater bounce at the front of the rim. Likewise, the fact that it is bolted down in the back may give the greatest bounce in the back because the ball makes contact with a solid surface that does not deform, so the ball does not slow down previous to changing direction and bouncing off the rim.

The ball must be released from freefall, as that is the only way to achieve dependably repeatable results. There are too many uncontrollable factors when not dropped from freefall. It is practically impossible to guarantee that the way that the ball is released from a shooter's hand will be precisely the same each time, and therefore the only force that the ball will experience will be the force of gravity.

The placement of the ball over a particular section of the rim when dropped is the independent variable. By changing the location on the rim that the ball hits, the energy that the ball loses after bouncing, which is the dependent variable, can be measured, and therefore a relation can be found. The distance the ball travels upwards will be measured using a measuring tape, which will be taped to the backboard and placed right above where the rim starts. A camera facing the backboard will record the bounce height achieved by the ball.

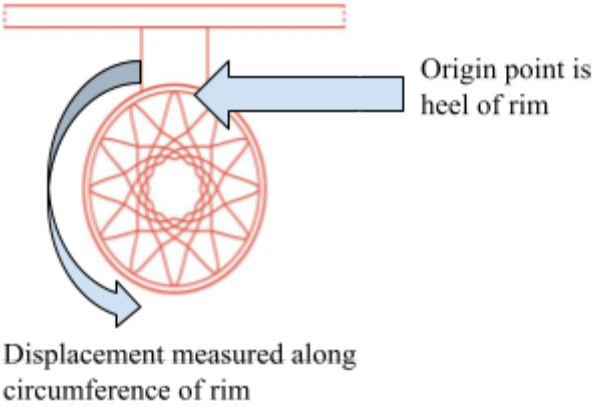
Research Question: How does the energy, measured in joules (J), that a basketball loses after bouncing on the rim depend on the displacement from the heel at which it is dropped?

Independent Variable: Displacement in meters (± 0.001 m) along the circumference from heel of rim. Check figure 3 for clarification.

Dependent Variable: Vertical distance in meters (±0.05 m) travelled by the basketball after making contact with the rim. The distance will be measured from the beginning of the rim to the peak of the ball's bounce.

Note that the uncertainty in all of the lengths is ±0.05 m because although the smallest measurement on the measuring tape is 0.001 m, there is human error involved when reading the ball's maximum height from the camera footage, which will increase the uncertainty a substantial amount.

Figure 2: Origin point of rim
Image from dimensions.guide



Control Variables:

Figure 3: Control Variables Chart

Control variable	**How it will be controlled**	**Why it needs to be controlled**
Level of the rim	A level tool will be used to ensure that the rim is levelled throughout. If it is not levelled, the rim will be adjusted or a more levelled rim will be used if the other rim is unfixable.	If the rim itself is not completely parallel to the ground all the way through, then some areas of testing may be uneven, and will result in data that is skewed. For instance, if a location is tilted upwards while another is tilted downwards, then the distance that each ball is travelling for each trial will not be the same. The ball will also not bounce perfectly upwards on an uneven rim.
Part of ball that makes contact with rim	There will be a camera placed directly underneath the rim that will be used to identify where on the ball the rim made contact. The rim must make contact with the center of the ball for the trial to pass.	If the ball does not hit the rim at the center of the ball, then when the ball bounces, it will not travel perfectly upwards. Instead, it will also have a horizontal distance as well. This will result in faulty data, because the maximum vertical distances would not have been found. However, if the ball does land directly centered on the part of the rim that it makes contact with, then it will bounce vertically upwards, as it was dropped directly downwards, and therefore the normal force will be directly upwards (Boston University Physics, Physics.bu.edu)
Height at which basketball is dropped over rim	All balls will be measured for their height above the rim using a measuring tape before each trial. They will all be dropped exactly 2 m (±0.05 m) above the rim. This will ensure that all of them start off at the same spot.	When the ball is suspended above the rim, it has potential energy. The higher the ball is from the rim the more potential energy it has. This is because potential energy takes into consideration the height of the ball above the rim. The equation goes as follows: potential energy = mass x gravity x height (ChemPages Netorials, Thermodynamics: Kinetic and Potential Energy). As the ball is dropped, that potential energy changes to kinetic energy. However, the balls must all have the same amount of energy, because when the ball hits the rim, if they do not have the same amount of energy each time, the ball will go further in some trials than in others. More energy, means more ability to do work, and therefore a further vertical distance will be achieved by the ball.

Figure 4: Control Variable Chart

Control variable	How it will be controlled	Why it needs to be controlled
Air pressure inside ball	In the beginning and end of the trials a pressure gauge will be used to ensure that the pressure remains the same, so that each attempt is fair. The same basketball will also be used, so that the pressure remains constant and one trial does not receive more bounce due to an over pumped ball.	The more air inside a basketball, the more pressure, and pressure is expressed as force divided by area. The air inside the ball is pushing outwards, so the more air inside the ball, the more molecules that strike its inner wall, and the more frequently they do so (Peter Staples, SportsRec). This means that the greater the air pressure, the more force the ball will exert on the rim when they make contact, and according to Newton's third law, if an object A exerts a force on object B, then object B must exert an equal (in terms of magnitude) and opposite (in terms of direction) force on object A (NASA, Newton's Third Law Applied to Aerodynamics). Thus, the normal force acting on the ball by the rim will be greater when there is a greater pressure in the ball, which will result in a further vertically upwards distance achieved by the ball
Spin on ball	All balls will be dropped in a manner that does not allow any spin. They will strictly be suspended in the air and released so that the balls are immediately in freefall. There will also be 2 cameras recording at different angles that will be able to show whether or not the ball had spin on it when it was dropped.	If a basketball has spin on it, the direction that it bounces in will be the direction that it is spinning in (Chad Orzel, Forbes). So even if the ball lands directly centered on the rim, if it is spinning it may change directions instead of going directly vertically upwards. This is an issue, because it means that the maximum vertical height has not been achieved. However, without any spin on the ball, the ball will be able to move strictly vertically, which will allow for much more accurate data.

Apparatus List:

- 1 Level (tool)
- 1 Roll of Masking Tape
- 1 Meter Stick
- 1 Basketball
- 1 Basketball rim
- 1 Air Pump
- 2 Cameras
- 1 Measuring Tape
- 1 Pressure Gauge
- 1 Ladder

Method:

1. Pump a basketball to 8.0 psi (± 0.1 psi).
2. Lower a basketball rim to its lowest possible height setting.
3. Using a tape measure, measure half of the circumference of the basketball rim. In this case, half of the circumference was 0.772 m (±0.001 m).
4. Mark with masking tape 5 points on half of the rim that are all equidistant to each other. In the case of a 0.772 m (±0.001 m) half of a circumference, the distance between each marked point will be 0.193 m (±0.001 m). Make sure that there is a mark on the very back, the very front, the side, in between the side and the front, and finally in between the side and the back .
5. Place a ladder right next to the rim or stand on some type of ledge, so that the experimenter can drop the basketball 2 m (±0.05 m) above the rim
6. Use a measuring tape, starting from the rim, going vertically upwards, for 2 meters. Masking tape can be used to tape the measuring tape to the backboard, to ensure the measuring tape does not shift from its position.
7. Place one camera directly below the rim and begin recording. This camera will be used to see if the ball drops perfectly centered on the rim during each trial.
8. Place a second camera facing the rim and the backboard. This camera will be used to see how vertically far the ball travels after making contact with the rim.
9. Drop the ball on the mark for the back of the rim from 2 meters high (±0.05 m), measured with the measuring tape.
10. Repeat five trials for the back of the rim, dropping it with zero spin, and from 2 meters high (±0.05 m).
11. The data for each trial should be easily recognizable from the camera facing the backboard. After 5 trials from the back of the rim, record the data from the camera, identifying the different heights achieved from each trial. Use the measuring tape as reference.
12. Repeat steps 9-11 for all of the other rim location variations.

Note:
The psi uncertainty is ± 0.1 psi because the pressure gauge used was analogue, and the smallest unit was 0.2, which, when divided by 2, is 0.1 (analogue uncertainty is half of the smallest unit).

The displacement along the circumference from the heel of the rim's uncertainty is ± 0.001 m because a measuring tape with an accuracy of up to 0.001 meters was used and for distance the uncertainty is simply the smallest measurement.

The height uncertainty for the basketball's bounce is ± 0.05 m because it is more appropriate, and accounts for both human and systematic error. This error includes inaccuracies in measuring the absolute peak of the ball's bounce, or the angle/location at which the camera measuring the ball's bounce is placed.

Safety and Ethical Considerations:
It is significant that throughout the experiment, precautions are taken and safety is always prioritized. This lab requires the experimenter to stand over a basketball rim on a ladder. This does have some safety risks, as injury can occur if the experimenter is not careful, and does not secure their balance throughout the procedure. Other than the ladder, there are no other safety hazards, and the lab is relatively very safe. However, the rim and the backboard can cause serious injury if the experimenter happens to fall from the ladder. That is why it is very important that the person performing the trials is always balanced. It may help if another person stabilizes the ladder while the other person drops the basketball on the rim.

This lab has no ethical concerns. It does not deal with anything harmful or damaging to the environment or others, and it can not harm any other life forms. However, this lab does emphasize the relationship between physics and sports, exposing and supporting the idea of living a healthy lifestyle by staying active, while always being intellectually curious about how physics makes the world the way it is. This lab can show the importance of seeking knowledge and staying in shape by blending both ideas into one.

Qualitative Data:
Figure 5: Peak Height of Ball

Distance from Rim's heel (± 0.001 m)	0 (Back)	0.193 (Back-side)	0.386 (Side)	0.579 (Front-Side)	0.772 (Front)
Vertical Peak	Self made photo The basketball's peak is very high. It's vertical distance travelled is significant and it clearly bounces back with a lot of energy.	Self made photo Bounces back a substantial amount. It peaks noticeably high, and clearly has a lot of energy on its way up after hitting the rim.	Self made photo Somewhat similar to the bounce on the left back portion of the rim. Ball travels vertically up with a smaller amount of energy, covering a less noticeable amount of vertical distance	Self made photo Ball's bounce is very minimal. The vertical distance covered after hitting the rim is observable, but it is nothing notable. Ball clearly loses a lot of energy after hitting the rim.	Self made photo Very little bounce. Vertical distance covered is infinitesimal. Ball hits the rim and almost immediately falls down. Barely any energy in ball after hitting rim.

Quantitative Data:

Figure 6: Aerial View of Rim (Image from

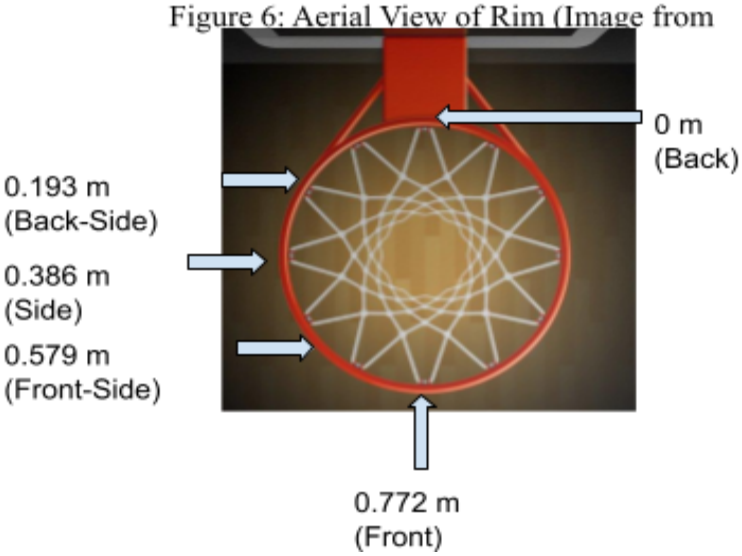
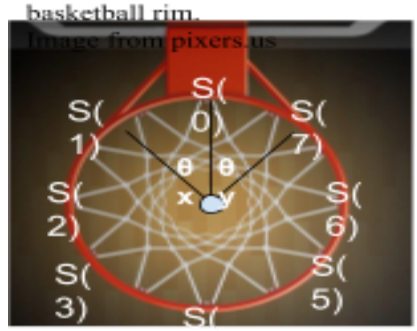


Figure 7: Sample Calculation of symmetry of basketball rim.



Sample Calc:
$\theta x = \theta y$
Therefore:
$s(1)=r(\theta x)$
$s(7)=r(\theta y)$
But
$\theta x = \theta y$
thus
$r(\theta x)=r(\theta y)$
And
$s(1)=s(7)$

The rim has a circumference of 1.544 m (±0.001 m), and because the rim is bilaterally symmetrical, if cut perpendicular to the backboard, the measurements taken only need to be for one side of the rim (left or right), as both sides will yield the same results. Refer to figure 7.

Figure 8: Maximum Height (±0.05 m) Achieved by the Basketball Depending on the Distance along Rim from Back (±0.001 m) Where it is Dropped

	Maximum Height (±0.05 m) Achieved by Basketball					
Distance along Rim from Back (± 0.001 m)	Trial 1	Trial 2	Trial 3	Trial 4	Trial 5	Average
0	1.17	1.20	1.19	1.27	1.22	1.19
0.193	0.84	0.87	0.86	0.78	0.81	0.83
0.386	0.44	0.59	0.48	0.60	0.55	0.53
0.579	0.23	0.20	0.22	0.25	0.26	0.23
0.772	0.09	0.07	0.12	0.12	0.11	0.10

Processed Data:

Figure 9: Justification of Processed Data Techniques

Processed Data Type	**Reason Behind Method**
Total energy loss of ball	Before the ball is dropped, the ball has only potential energy, as it is not in motion. The ball is then released and hits the rim, losing some of its energy as the rim absorbs it. The ball then bounces off the rim and peaks at a vertical distance. During the peak, the ball once again has only potential energy, as it again is not in motion. The loss in potential energy can be shown by the difference in height between when the ball is initially not in motion and when the ball has reached its peak. This will convey what location on the rim absorbs the most energy and therefore what location is least ideal for the greatest vertical bounce. Formula: $(KE_i+PE_i) - (KE_f+PE_f) = \Delta E_t$

Figure 10: Justification of Processed Data Techniques

Processed Data Type	Reason Behind Method
Standard deviation of total energy loss (J) of the Basketball	The standard deviation will show how the basketball's loss in energy varies from the mean energy loss that was achieved for each rim location. With this information, a judgement can be made on how much the data varied and thus how reliable and precise the data is. Standard deviation was calculated through excel. $\sigma = \sqrt{\frac{\Sigma (X - \overline{X})^2}{n-1}}$
Correlation Coefficient	The correlation coefficient measures how strong a relationship between two variables is. This will showcase the strength of the relationship between the rim's location and the basketball's average total energy loss, and it will demonstrate whether or not they truly are correlated. Correlation coefficient was calculated through excel. $r = \frac{1}{n-1} \Sigma \left(\frac{X - \overline{X}}{s_x}\right)\left(\frac{Y - \overline{Y}}{s_y}\right)$
T-test	A t-test determines if there is a significant difference between the means of two groups, which allows for the average values of two data sets to be compared to determine if they come from the same population. In the case of this particular lab, the value of a T-test is that it will demonstrate whether the trends found in the changing basketball heights were by chance or if they were a direct result of the change in rim location. The T-test will be found using excel. T-test may be inappropriate however, because the limited amount of data may yield inaccurate results. $t = \frac{\bar{x}_1 - \bar{x}_2}{\sqrt{s^2\left(\frac{1}{n_1} + \frac{1}{n_2}\right)}}$ $s^2 = \frac{\sum_{i=1}^{n_1}(x_i - \bar{x}_1)^2 + \sum_{j=1}^{n_2}(x_j - \bar{x}_2)^2}{n_1 + n_2 - 2}$

Figure 11: Initial Total Energy and Average Total Energy at Peak Depending on Distance along Rim from Back (±0.001m)

Distance along Rim from Back (±0.001m)	Basketball Mass (± 0.01 kg)	Average Maximum Height (±0.05 m)	Initial Total Energy (± 0.5 J)	Average Total Energy at Peak (±0.5 J)	Average Total Energy at Peak Uncertainty
0	0.62	1.19	12.2	7.24	0.42
0.193	0.62	0.83	12.2	5.04	0.38
0.386	0.62	0.53	12.2	3.22	0.36
0.579	0.62	0.23	12.2	1.40	0.33
0.772	0.62	0.10	12.2	0.61	0.31

Figure 12: Total Energy Lost (J) in the Basketball at Each Rim Location (±0.001m)

	Total Energy Loss (J)						
Distance along Rim from Back (±0.001m)	Trial 1	Trial 2	Trial 3	Trial 4	Trial 5	Average Total Energy Lost (J)	Average Total Energy Lost Uncertainty
0	5.08	4.90	4.96	4.48	4.78	4.96	0.92
0.193	7.09	6.91	6.97	7.46	7.27	7.16	0.88
0.386	9.52	8.61	9.28	8.55	8.85	8.98	0.86
0.579	10.80	10.98	10.86	10.68	10.62	10.8	0.83
0.772	11.65	11.77	11.47	11.47	11.53	11.59	0.81

Initial total energy was calculated by the equation PE = mgh, which depends on gravity, the mass of the basketball, and the height at which the ball is dropped. This is because the object is stationary and all of its energy is potential. Likewise, with the total energy at the peak, all of the energy is potential again, so the same equation was used. Ex: 0.62 x 9.81 x 2 = 12.2 J

Initial total Energy uncertainty calculation: Because there is multiplication of numbers that have uncertainties involved, this equation must be used: $\frac{\Delta y}{y} = \frac{\Delta a}{a} + \frac{\Delta b}{b}$

Substituting the values results in: $\frac{\Delta y}{(0.62*9.81*2)} = \frac{0.01}{0.62} + \frac{0.05}{2}$

Therefore uncertainty in initial total energy = ± 0.50031 = ± 0.5 J

The same equation was used to find the uncertainties of the total energy at peak for each trial. The uncertainty of the initial total energy was then added to the uncertainty of the final total energy to find the uncertainty of the total energy lost. This was done because numbers with uncertainties are being subtracted, so this equation was followed: $\Delta y = \Delta a + \Delta b$

Figure 13: T-test Displaying the Significance of the Total Energy Loss Based on the Change in Rim Location (±0.001) m

Null Hypothesis: There is not a significant difference between the height of the ball achieved at the heel of the rim location and the height of the ball achieved at one of the other rim locations; any observed differences may be due to chance and sampling error.

Alternative Hypothesis: There is a significant difference between the height of the ball achieved at the heel of the rim location and the height of the ball achieved at one of the other rim locations; the observed differences are most likely not due to chance or sampling error.

Distance along Rim from Back (± 0.001 m)	P-Value	Accept/Reject Null Hypothesis
0-0.193	0.000000243093	Rejected
0-0.386	0.000000059202	Rejected
0-0.579	0.000000000035	Rejected
0-0.772	0.000000000011	Rejected

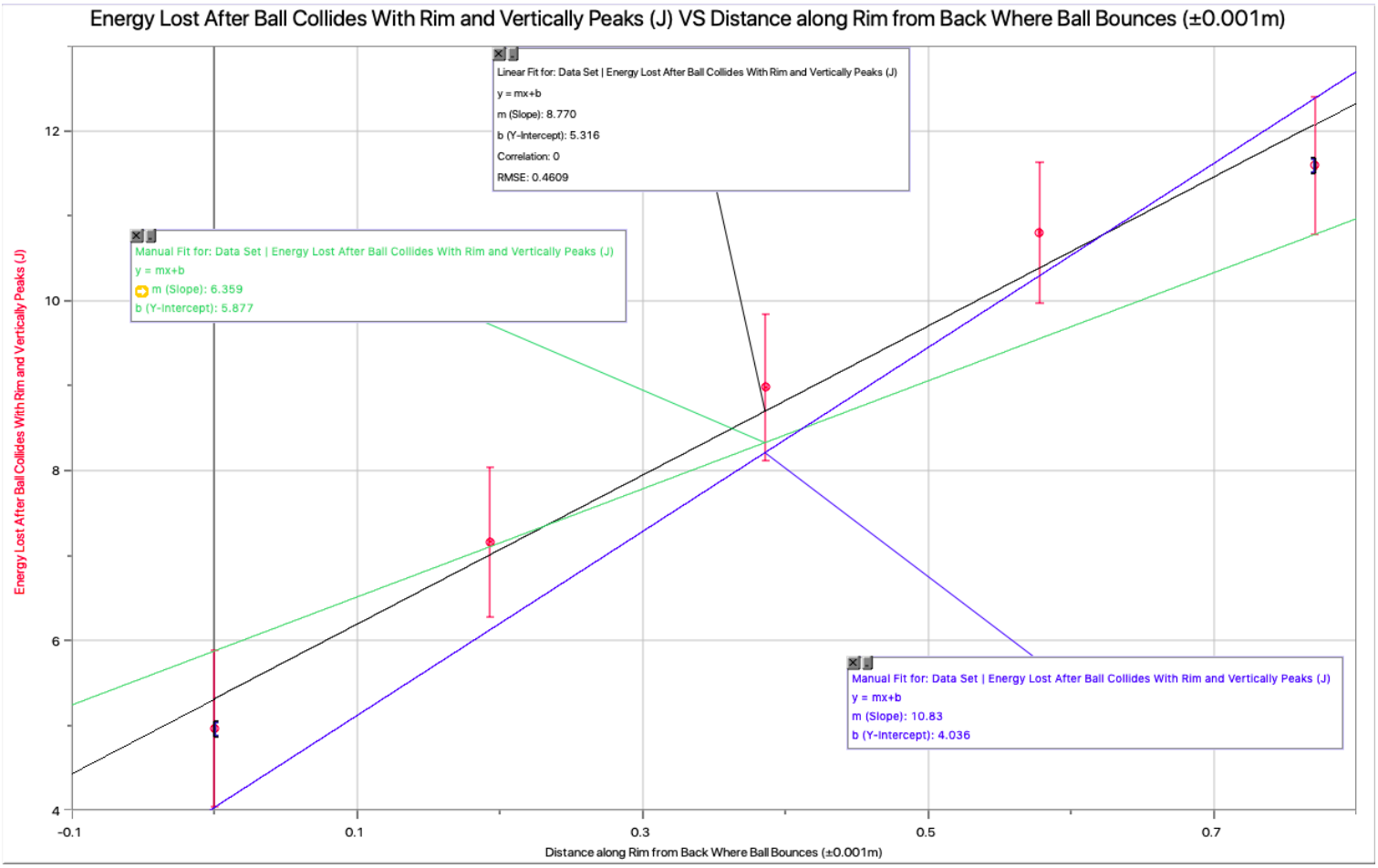
With this information, the conclusion can be reached that for all data ranges, the null hypothesis is rejected, as the calculated P−value is ≤ 0.05. A P-value of 0.05 or less is significant in which case the null hypothesis is rejected and the alternative hypothesis is accepted. This means that the differences in bounce height between the heel of the rim and the other locations was significant enough for it to not be explainable through random chance. Furthermore, the further the rim location from the heel of the rim, the less likely it is that the difference between the bounce heights is due to random chance.

Figure 14: Standard Deviation and Correlation Coefficient of Total Energy Loss and Distance Along Rim from Back (±0.001m)

Standard Deviation of Total Energy Loss	Correlation Coefficient
0.23	0.99
0.23	
0.42	
0.15	
0.13	

Standard deviation and correlation coefficient were calculated using excel and a calculator. For the standard deviation, the total energy loss of each trial was calculated by subtracting the initial energy of 12.2 J by the product of the mass of the ball, acceleration due to gravity, and the ball's maximum height after making contact with the rim (mgh). Then the function STDEV was used to calculate the standard deviation. For correlation coefficient, the function CORREL was used, and the correlation between the distance from the back of the rim and the total energy loss was calculated.

Graph:
Figure 15:



Black line is the line of best fit (slope of 8.77 J/m)
Blue line is the maximum slope line (slope of 10.83 J/m)
Green Line is the minimum slope line (slope of 6.36J/m)

All error bars for rim location are the same, as the rims circumference was measured using a device accurate to 0.001m
The error bars for the average total energy loss are unique to each rim location because they all have different changes in peak heights, which affects the calculation of $\frac{\Delta y}{y} = \frac{\Delta a}{a} + \frac{\Delta b}{b}$ in order to find uncertainty.

The trend that can be seen is that as the rim location gets further away from the back of the rim, which is bolted down into the backboard, there is an increase in energy loss within the ball. This is what is causing the ball to have a lesser peak height after bouncing off the rim. The energy that the ball carries after making contact with the rim decreases by a substantial amount (on the front of the rim it is an energy loss of 11.59 J compared to at the back where it is only a loss of 4.96 J) as the ball makes contact with rim locations further away from the back. The line of best fit passes through all of the data points, which shows a great amount of accuracy within the data. This is because it shows that the trend in the data can be accurately represented by a line that supports and agrees with all of the points that are marked on the graph.

Conclusion:
In conclusion, the hypothesis was correct, and it is supported by the data. The more the ball moved away from the heel of the rim, the less the ball would bounce vertically up. This is because the area that is bolted down is the hardest and has the least amount of give. In other words, it is the least springy when it makes contact with the rim, and because of that, it does not absorb a lot of

energy from the ball when contact is made. Instead,the rim returns the most energy back to the ball, thus allowing it to cover a greater vertical distance.

The data agrees with this claim, as can be seen from how when the ball hits the front of the rim, the ball has an average peak of 0.10 meters. However, when the ball hits the back of the rim, the ball has an average peak of 1.19 meters. That is an increase of about 99 percent. This shows how significant of a change the difference in rim location makes, and how much greater of a bounce can be achieved by utilizing the back of the rim. Furthermore, the change in bounce is consistent with the change in rim location, because as the ball gets further away from the bolted area the energy loss increases and therefore the maximum height achieved by the ball decreases. For example the maximum height goes from 1.19 to 0.83 to 0.53 to 0.23 then finally to 0.1 meters as the ball shifts from 0 to 0.193 to 0.386 to 0.579 to 0.772 meters along the rim from the back, respectively. This is further supported by the strong correlation coefficient of 0.99 between the distance from the back of the rim and the energy loss of the ball. Therefore, as the ball moves further from the bolted down area of the rim, the ball loses more and more energy.

The graph shows this trend too, as can be seen by the positive slope of 8.77. This positive slope means that both the loss in energy and the distance from the bolted down part of the rim is increasing. This again suggests the idea that the rim's bolted area supplies the greatest vertical bounce because it is best at ensuring the ball's energy loss remains minimal. Furthermore, the data within the T-test shows that the changes within the rim locations has a significant effect on the energy loss. This demonstrates how substantial the differences in the different heights of the ball are when changing the location on the rim where the ball is dropped.

An experiment by Scientific American also arrived at this same conclusion by testing different surfaces of different hardness levels to see which surface allowed the ball to bounce the highest. Harder surfaces like concrete were much better at this than softer surfaces like carpet. The explanation here was that more energy was wasted with softer surfaces. Energy is wasted with the carpet surface for instance, in order to move the individual pieces of yarn (University of Illinois, Ask the Van). In the case of the rim, the further the ball bounces from the heel of the rim, the more energy is used to deform the rim, leaving less energy for the ball to bounce with.

The results of this experiment are exceptionally reliable, particularly because of how drastic the differences are with the vertical bounce height at each rim location. Because there is such a large difference, it is easier to record and recognize the obvious tendencies of the rim. Furthermore, the use of multiple cameras at different positions and the utilization of data processing software such as loggerpro made sure that the data collection and data processing stages were reliable and carefully thought out.

<u>Evaluation:</u>

Figure 16: Identification of Strengths

Strength:	**Explanation:**
Simple procedure	This experiment is very easy to perform once one has the necessary tools. It does not require a lot of complex physics skills, as it mostly deals with measuring distances (circumference of the rim, drop height, vertical upwards distance). The procedure can also be performed in any place with a basketball rim, so it does not need to be done in a special lab.
Easy to control the pressure variable	The pressure of the ball is very necessary to control, because the pressure can directly affect the bounce that the ball has, as previously explained. This lab makes it very easy to control the pressure, because the experiment itself does not take long to complete, and if the experimenter uses the same ball throughout, the pressure will not change at all throughout the procedure (or the change will be ultimately infinitesimal). Furthermore, the use of a pressure gauge can further guarantee a steady and constant pressure in the ball.
Demonstrates a clear correlation between physics, sports and the everyday world	This lab makes it very easy to comprehend how physics is integrated in not only sports, but the entire world around us. The idea of potential energy converting to kinetic energy as an object is dropped, and the idea of the normal force being equal to the force of weight are all things that are witnessable in everyday life. This exacerbates the idea that physics is significant in achieving a better understanding of the world around us and how it works.

Figure 17: Identification of Strengths

Strength:	Explanation:
Results are easy to quantify and raw data can be processed using physics equations that yield accurate results	The use of a camera makes it very easy to measure where on the measuring tape the basketball stops at, which makes it very easy to tell where the ball peaks after making contact with the rim. This results in very accurate data, which can then be processed with physics equations to show more complex solutions (while still maintaining accuracy and reliability in data).
Utilizes Gravity to its advantage	Gravity is quite possibly the most accessible thing across the world, and it is also a constant that is used to this lab's advantage. As previously mentioned, when a basketball is shot normally, there are so many different factors that make the shot unrepeatable. Furthermore, different people have different shot forms, which will result in different amounts of spin and shot angles when this lab is performed. However, everyone has access to gravity, and gravity never changes, and is therefore highly repeatable. Thus, utilizing gravity makes this lab much more universally practical, as it is a constant that yields precise results every time.

Figure 18: Identification of Weaknesses

Weakness:	Explanation:	Possible Improvement:
Difficult to guarantee a strictly vertical bounce	The bounce must be completely vertical for the results to show the maximum vertical distance achieved by each rim location. However, achieving this result is not easy, because the ball is round and the rim is also round. Trying to make perfect contact between two round objects is very difficult and hard to repeat for multiple trials.	Performing more than 5 trials for each rim location variation will lead to a more accurate average of the maximum vertical distance achieved. By performing more trials, there will be a greater amount of data to choose from, and therefore a more accurate depiction of the actual result.
Basketball may not be perfectly round i.e. deformations	A basketball can become deformed after a while when the elastic materials begin to degrade (Somasundaram Valliappan, msp.org). This can result in a ball that bounces irregularly. This irregular bounce can mean that the ball's lack of uniformity will cause some areas of the ball to bounce higher than others when they make contact with another surface. An irregular ball will lead to untrustworthy data, because the ball's bounce will be unpredictable.	Using a new basketball that has not been exposed to overuse or overheating will mean that the ball is perfectly shaped and not irregular in any way. This means that the ball will demonstrate an equal bounce no matter where on the ball it makes contact with another surface. This uniformity will make the data collection much more reliable and the systematic error will decrease.
Hard to accurately determine where to drop the ball for measurements further from the backboard	The measuring tape is taped to the backboard, and it serves as a reference point so that the experimenter knows where to drop the basketball so that it is dropped exactly 2 m above the rim (±0.05 m). However, because it is taped to the backboard, it is hard to accurately depict where 2 meters is located when working on the trials for the front of the rim. This is because the front of the rim is far from the backboard, and it is hard to guarantee that the place that it is dropped is completely accurate to 2 meters.	Because the person dropping the basketball for each trial must use both hands to ensure a perfect drop, there could be another person holding the measuring tape at each location that the ball is being dropped at. This will make it easier for the experimenter to drop the ball at a much more accurate location above the rim, which will therefore result in more reliable data.

Figure 19: Identification of Weaknesses

Weakness:	Explanation:	Possible Improvement:
Camera angles for both cameras may be unaligned with rim, resulting in a skewed perspective	Two cameras are used in this lab. One is directly beneath the rim to ensure that the ball is centered on the rim when it makes contact with it, and the other camera is facing the backboard to detect the maximum vertical distance achieved by the basketball after each trial. However, both of the results that are presented on the footage may be inaccurate if the angle at which the cameras were filming in were not straight, or if they favored one angle over another (as opposed to being completely parallel to the rim/backboard).	Using a tripod would allow for the camera to be steady and for it to be easily straightened up and matched up with the backboard. This will result in the data collection process being a lot more reliable, as the angle that the ball is seen to peak at can be properly compared with the measuring tape on the backboard.
Difficult to ensure a perfect drop for each trial	A perfect drop means that the ball is not thrown upwards initially, and that there is zero spin on the ball as it falls. This is very hard to guarantee, because naturally, there will be human error involved in each throw, even if the error is minimal. Achieving the perfect throw is very challenging for humans, because repeating a movement that requires such detail and attention is not simple. This differentiation in the drops can result in a deviation in the data collection, and decrease the dependability of the data.	A mechanism could be used and placed above the rim to drop the basketball onto the rim. The mechanism could be a pulley system that released the ball on command, or a basket with a hole in it that is perfectly shaped for the basketball's size. This will result in a much more stable and reliable drop, as the human error will be removed. The mechanism can be moved to be placed right over the location of the rim that is being tested. That way, the ball lands perfectly centered on the spot, and there is no spin or imbalance when contact is made.
Rim could have had an external factor that changed the results, such as a loose bolt	If there were to be a loose bolt on one of the basketball hoops, then the integrity of the rims would be at stake. Since the rim is the most important part of the procedure, ensuring that there are no faults or unexpected variables is a top priority. A loose bolt would mean that one side is weaker on the rim than it should be, which could lead to irregular data, because it may affect the energy absorption of the rim.	Testing the procedure on multiple rims can yield more reliable data, as an average can be calculated, and averages are always more accurate when there is a wider range of trials. If 5 rims were tested and there were a lot of outliers on one rim, it would be clearer that there is a fault in that rim, and that the data collected from that rim is unrealistic and does not support the rest of the data.

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