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Bouncing Ball

Introduction

There are various factors that affect the speed, height, time and number of bounces of a bouncing ball. The main questions that were being analyzed in this experiment were: what is the relation between the height from which the ball is dropped and the time in which it bounces? And does the mass of the ball affect the time the ball takes to fall and bounce?

When a ball is dropped on the floor, it bounces off at a speed that is proportional to the speed at which the ball was dropped. The dropping and bouncing ball contains different forms of energy namely kinetic energy and potential energy. The kinetic energy of the ball is dependent on the speed at which the ball was dropped. On the other hand, potential energy of the ball depends on the height from which the ball was dropped. The kinetic energy (KE) and potential energy (PE) are calculated using equation 1 and 2 respectively, as shown below

$$KE = ½ * m * v^2 \quad \ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots (1)$$

Where m = mass of the ball and v = velocity at which the ball is dropped

$$PE = m*g*h \quad \ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots (2)$$

Where m = mass of the ball, g = gravitational acceleration, and h = drop height

Hypothesis

The prediction in this experiment is that the bounce height is directly proportional to the height from which the ball was dropped. This means that a ball dropped from a higher point will record a high bounce height the one dropped from a lower point. This is basically because a ball dropped from a greater height possesses more potential energy which is transformed into kinetic energy when the ball is hitting the floor. It is this kinetic energy that enables the ball to bounce. It is also worth noting that the bounce height will definitely be less than the original height of the ball because as the ball moves and hits the floor, it loses some energy to heat, speed, sound and movement. Additionally, a ball with a higher mass possesses more kinetic and potential energy. This means that the ball will hit the floor with more force and therefore it will compress more and lose more frictional energy.

Variables

Some of the dependent variables in this experiment included height from which the ball was dropped and mass of the ball. Independent variables included speed at which the ball was dropped, temperature of the ball and room, air resistance or density, type of surface upon which the ball was falling, type of ball and material from which the ball was made.

Apparatus and Materials

The following are some of the apparatus and materials that were used in this experiment: tape measure, two tennis balls with different mass, measuring ruler, two clamps, stopwatch, retort stand and a table.

Procedure

Part 1:

This part involved using the same tennis ball and the only variable was the drop height. The tennis ball was raised to a height of 45 cm above the floor. The ball was then released to fall. As the ball bounced, its bounce height was measured by carefully looking at the bounce's peak against the measuring ruler that was positioned behind the ball. After recording the bounce height at the first height of 45 cm, the same procedure was repeated up to 130 cm at 15 cm increments. The value of bounce height was recorded to the corresponding height of drop in a table.

Part 2:

This part involved using two balls with different masses. The balls were dropped from the same height and the time it took for the balls to bounce was recorded. The experiment started by raising the first ball to a height of 45 cm above the floor. The ball was then released to fall freely and a stopwatch was started simultaneously. The time at which the ball hit the floor and made the first bounce was recorded. The second ball was raised to the same height of 45 cm above the floor. It was then released to fall freely and a stopwatch was started simultaneously. The time at which the ball hit the floor and made the first bounce was recorded. These steps were repeated for at different heights of up to 130 cm with 15 cm increments. The values of time for the two balls were recorded in a table.

There were some measures that were taken during the experiment to ensure consistency of the experiment. Some of these included: the same tennis ball was used at all heights; the ball was dropped from directly above and aimed at the same point of floor; all windows of the room were closed to prevent effects of wind and temperature; a clamp was used to drop the ball so as to maintain consistency.

Results

Data:

Drop height (cm)	Bounce height (cm)
45	25
60	35
75	42
90	50
105	55
120	65
130	70

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Table 1: Experimental data for part 1

Drop Height	Time for first bounce (s)	
	40 g	70 g
45	2.0	2.2
60	2.4	2.5
75	3.0	3.1
90	3.5	3.7
105	3.8	3.9
120	4.4	4.5
130	4.8	4.8

Table 2: Experimental data for part 2

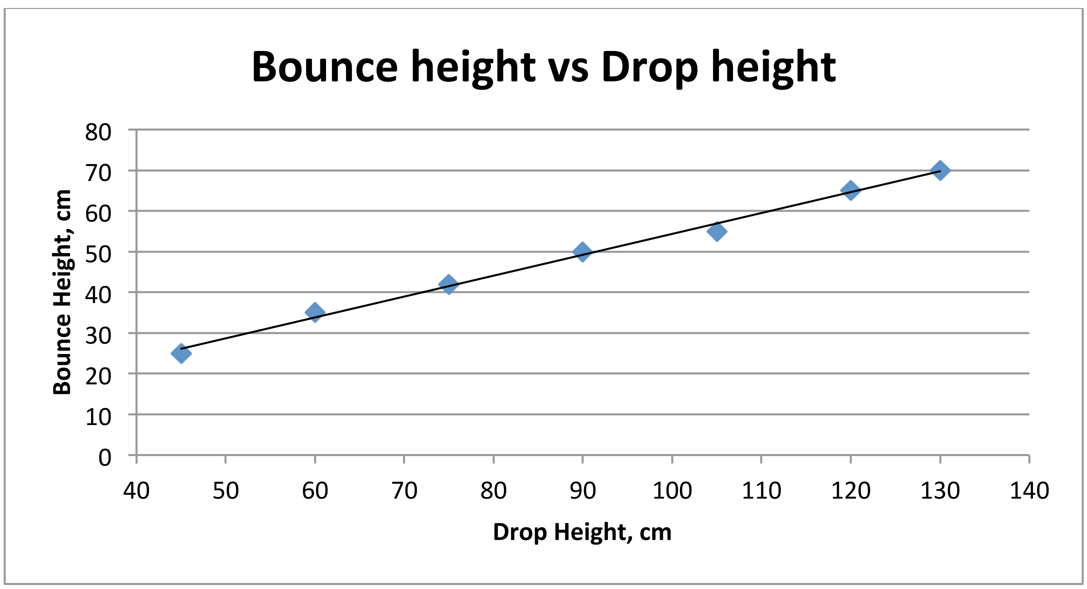

Figure 1: Bounce height against drop height

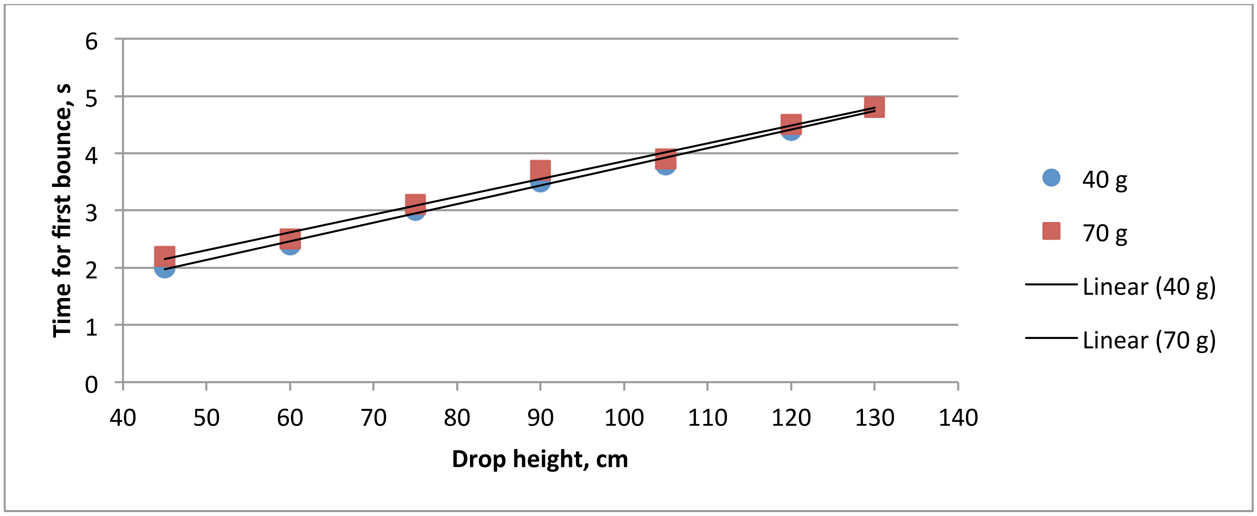

Figure 2: Time of first bounce against drop height

Discussion

The graph in Figure 1 above shows that the bounce height was directly proportional to drop height i.e.

$$BH = kDH \quad \ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots \quad (3)$$

Where BH = bounce height, k = constant – slope of the graph, and DH = drop height.

In other words, an increase in drop height of the tennis ball resulted to a corresponding increase in bounce height. When the tennis ball was lifted before being dropped, it gained more potential energy. The potential energy was specifically gravitational potential energy, which is the energy gained by a body when its height above the ground is increased. Since the tennis ball was of the same weight, it means that its gravitational potential energy increased with an increase in drop height.

When the tennis ball was dropped, its gravitational potential energy started being transferred into kinetic energy. The kinetic energy resulted from the motion of the ball. The ball's kinetic energy continued increasing as the tennis ball gained momentum, until the ball hit the floor. When the ball hit the floor, the kinetic energy was transferred into other types of energy including thermal energy, sound energy and elastic potential energy. The sound energy was as a result of the energy produced when the ball collided with the floor. The thermal energy was as a result of friction created between the surface of the ball and the floor. Elastic potential energy resulted from the deformation of the ball immediately after hitting the floor.

The elastic potential energy was the one that caused the ball to bounce. After rebounding, the ball's elastic potential energy was transformed into kinetic energy. Nevertheless, the kinetic energy was not as much as the one that was originally possessed by the ball when it was being dropped for the first time. This therefore means that the ball could not bounce off to the original height because some of its kinetic energy had been transferred to thermal energy, sound energy and friction energy.

Therefore the bounce height increased with the increase in drop height because an increase in drop height results to an increase in gravitational potential energy, if all other factors remain constant. It is this gravitational potential energy that is later transformed into kinetic energy that pushes the ball as it drops and after bouncing.

The graphs in Figure 2 show that the heavier ball (70 g) took slightly more time to make its first bounce than the lighter ball (40 g). Since the balls were raised to equal heights each time, it means that their potential gravitational energy was determined by their mass. In this case, the 70g ball had higher gravitational potential energy that the 40g ball at equal heights. Since the 70g was heavier and had higher gravitational potential energy, it means that the effect of air resistance on it was less compared to the 40g ball. This implies that the 70g ball dropped faster than the 40g ball because its high gravitational potential energy was converted into kinetic energy that enhanced the downward movement.

Therefore

$$T = kDH \quad \text{………………………………………………………….. (4)}$$

Where T = time for first bounce, k = constant – slope of the graph, and DH = drop height)

The 70g ball had more kinetic energy than the 40g ball when it was hitting the floor. The force of the impact was very high for the ball to absorb and therefore it deformed and lost its bounce. This is because more energy was released in form of friction, sound and deformation. In other words, the 70g lost a significant amount of energy on hitting the floor. On the other hand, the motion of the 40g ball was affected more by air resistance thus slowing down the ball. The 40g ball also had less gravitational potential energy and kinetic energy than the 70g ball. This implies that the 40g ball hit the floor with less impact and therefore its deformation was also less. In other words, the 40g lost less energy in form of sound, friction and deformation and therefore it did not lose much of its bounce.

It is worth noting that the graphs in Figure 2 almost overlapped each other and this is because the effect of mass on the time of bouncing of the ball is almost negligible because it cancels out. At first, the 70g ball had more gravitational potential energy. This energy was converted into kinetic energy. On hitting the floor, most of this energy was dissipated to other forms of energy. As a result of the high impact of the ball, the high amount of energy dissipated caused the ball to lose its bounce and therefore it took more time to rebound and make its first bounce. On the other hand, the 40g started with less gravitational energy. The energy was converted into kinetic energy. The ball hit the floor with less impact and thus it did not lose much of its bounce. Since it did not deform much, it took little time to rebound and make its first bounce. In general, the 70g started falling with high energy but it lost most of it on hitting the floor hence it rebounded with less energy. On the contrary, the 40g started with less energy and lost very little on hitting the floor hence it rebounded a bit faster to make it first bounce.

If air resistance was neglected then mass of the ball would not affect the speed at which the ball dropped and bounced after hitting the floor. However, air resistance is always present in real life situations and therefore mass of the ball had some effects on the time it took the ball to fall and bounce.

There were several possible sources of errors in this experiment. The balls were dropped from relatively lower level which increased uncertainties of time because it was not easy to take the time measurements. The uncertainty of stopwatch, tape measure and measuring rule could also have caused some errors. If any of these devices had some imprecisions, it means that these uncertainties were carried throughout the measurements and the final results. It is also possible that uncertainties would have resulted from the fact that only one measurement was made for each value required. This means that even if the person taking the measurement made a mistake, it was carried forward to the final results.

Another possible source of error was due to parallax. It was not easy to accurately measure the bounce height by eye. Inasmuch as all efforts were made to carefully look at the bottom of the ball horizontally so as to record the exact peak of the bounce, the value obtained was not very accurate.

Conclusion

The results obtained in this experiment proved the hypothesis that an increase in drop height of a bouncing ball results to a corresponding increase in the bounce height. In other words, the experiment proved that bounce height is directly proportional to drop height. The experiment further proved that when a bouncing ball is raised to a greater height, its potential energy increases which is later transformed into kinetic energy and dissipated to other forms of energy (heat, sound and deformation) when the ball hits the floor. It is due to this energy dissipation that the bounce height never reaches the original drop height of the ball.

The experiment also proved that the effect of mass on the time in which the ball bounces is usually insignificant because it ends up canceling out. The heavier ball starts with high energy but it later dissipates most of the energy on hitting the floor. This causes it to take a little longer to rebound and also loses its bounces. On the other hand, the lighter ball starts with less energy and loses very little on hitting the floor. This means that it does not lose a lot of its bounce.

The experiment was carried out carefully and all mistakes were minimized as much as possible. For example, the doors of the experiment room were closed to prevent uncertainties resulting from wind and temperature changes. The bounce height were keenly observed and recorded. The drop height was also accurately measured. Even though all these were not 100 percent accurate, the results obtained in this experiment were precise and reliable. This is because the graphs obtained in this experiment were similar to theoretical graphs.

This experiment could be made more reliable in the future by considering the following improvements: dropping the balls from relatively higher levels so as to reduce or eliminate uncertainties of time; ensuring that all devices used in the experiment had the highest level of precision desired; making more measurements and taking average as the value to be used in computing the final results; and using electronic measuring devices to record the exact bounce height.

Source

Museum of Science and Industry Chicago. (n.d.). *Ball Drop*. Retrieved from https://www.asee.org/conferences-and-events/conferences/k-12-workshop/2012/Ball_Drop_activity.pdf