Sample C

Criteria	**Teachers' mark**
Personal Engagement	0
Exploration	3
Analysis	2
Evaluation	3
Communication	3
Total	11

Rate of Drainage in Leaking Can

Research

The aim of this experiment is to investigate the relationship between the size of a hole in a can and the time it takes for the water to empty from the can. This will be done by changing the diameter of the hole in the can by using drill bits with known diameters. The time will be measured by simultaneously releasing the water into the can and starting the timer. The release and timer start will be synchronized by a simple countdown and the timer will stop once all the water has drained out of the container through the hole.

The primary force that is causing the drainage is the force of gravity on the water. Because the water is released into the can with a hole in it, gravity is going to pull the water through this hole. With a larger hole size, gravity can pull more of the water through the hole at the same time. Similarly, if there is a smaller hole, gravity is not able to pull as much water through the hole at once, increasing the time it takes to empty. Therefore, as the size of the hole increases, the time it takes for the can to completely empty decreases.

Variables

- The independent variable in this experiment is the size of the hole through which the water will be flowing, which will be measured in inches by the diameter of the hole.
- The dependent variable in this experiment was the time taken for the can to empty, which was measured in seconds through synchronization of release and start of the timer.
- To control the experiment, the same volume of water was used in each trial, the container was tilted at the same angle (45° above horizontal) to ensure complete drainage with the

angle being re-measured following each trial, the position of the hole in each of the drainage systems, and the synchronous timing of the drainage was used for every trial.

- The only factor that may not have been controlled was the accuracy and precision of the timings. Humans are not the most accurate at timing the experiment and even though measures were taken to limit the error through using a countdown upon release, there is still the possibility of error.

Method

1. Materials required are a graduated cylinder, a round Tupperware container (to be used as a can), a drill with multiple drill bits, water, plastic wrap, protractor, and a stopwatch.
2. Drill a hole in the bottom edge of the Tupperware using a drill bit of size 1/16 of an inch
3. Cover the hole with plastic wrap to prevent pre-timing drainage.
4. Pour 100 mL of water into the Tupperware over the plastic wrap.
5. Place the Tupperware so that the hole is the lowest point of the Tupperware and make sure the side of the container is at a 45° angle to the horizontal.
6. Remove the plastic wrap at the same time as the stopwatch starts.
7. Stop the stopwatch as soon as all the water has drained from the container. This is best done by having one person observing the contents inside the container and telling the person with the stopwatch to stop as soon as all the water has emptied.
8. Repeat steps 3-7 with this size hole 2 more times.
9. Expand the existing hole to a diameter of 1/8 inch and repeat steps 3-8.
10. Repeat step 9 with diameters of ¼ inch, 3/8 inch, and ½ inch.

Raw Data

Diameter of the Hole/ inches ± 1/64 inch	Time to Drain/ seconds ± .5 s		
1/16	171.9	174.5	172.6
1/8	29.5	28.7	29.5
¼	10.7	10.5	10.5
3/8	3.2	3.2	3.3
1/2	2.0	2.2	2.0

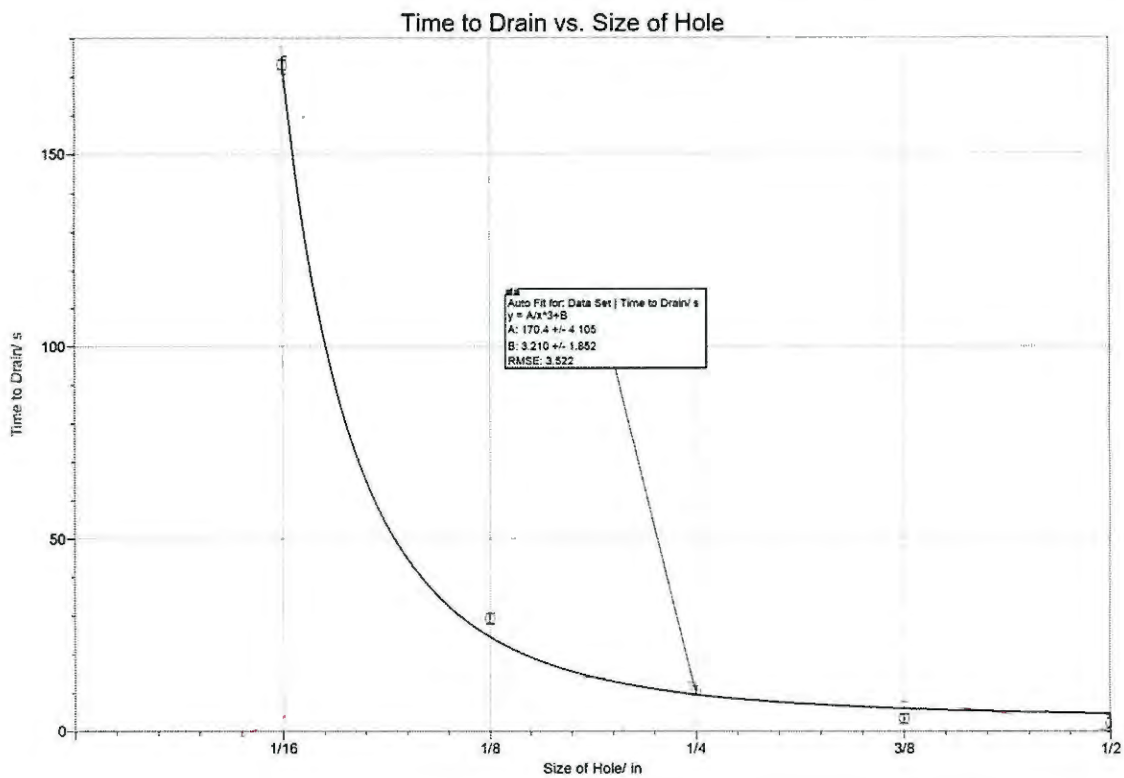
The uncertainty on the independent variable is due to the drill bits. When I was drilling the holes, I tried to make them no wider than the drill bit, but the drill bit may not be exactly the diameter it says it is. However, because the set of drill bits increased sizes by 1/64 of an inch, I believe that there is decent accuracy for the size of the bits on the diameter. The uncertainty on the dependent variable is due to the human timing of the drain. I feel that the human can get within .25 seconds of the verbal call therefore, to accommodate for both the start and stop verbal calls, I decided the uncertainty was ± .5 seconds.

Processed Data

Diameter of the Hole/ inches ± 1/64 inch	Average Time to Drain/ seconds ± 1.3 s
1/16	173.0
1/8	29.2
¼	10.6
3/8	3.2
1/2	2.1

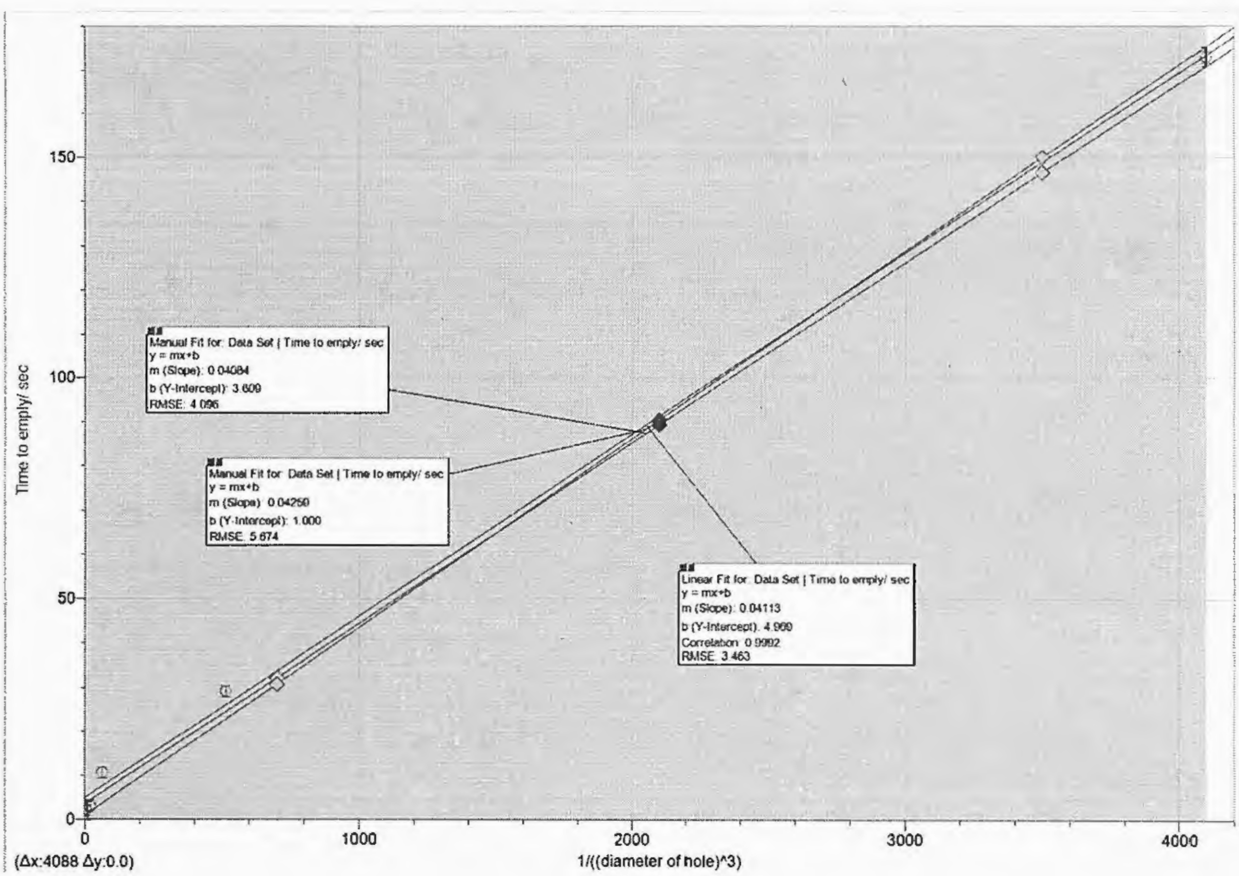
To calculate the average, I added the three results from the trials and divided that by 3. For example, for the 1/2 inch trial, $\frac{2.0+2.2+2.0}{3}$ to get 2.1 seconds. An example calculation of uncertainty is in the 1/2 inch trial, $\frac{2.16-1.96}{2}$ to get an uncertainty of .1 seconds. The uncertainty for the average is 1.3 seconds because the 1/16 inch trial had the greatest variance in time and this number encompasses all others.

Graph



With the data collected from the experiment, I placed the processed data into a graph as shown above. I next found that the type of function that best adhered to the data was a $1/x^3$ function. The equation for this curve is $y = \frac{170.4}{x^3} - 3.21$. I believe that this is because in the range of holes I used, there was difference between the sizes that created the hyperbolic shape, such as when the holes get bigger, the time will always be approaching 0 seconds, and as the holes get smaller, the time will always be approaching infinity. The curve of best fit does not go through all the data points most probably due to the error on recording the times. In order to find a linear graph, I will make the independent variable $1/x^3$ where the x is the data point that was collected and the dependent variable is still the time it took for the can to empty. The new x values for the graph are 8.000, 18.96, 64, 512, and 4096. The y-values will stay the same so that the new x values are still being compared to time.

Time to Drain vs. Size of Hole



In this graph, the slope of the line of best fit is .0411 and the minimum and maximum slopes are .0408 and .0426 respectively. This leads to an uncertainty on the slope to be $\frac{.0426-.0408}{2} = .000900$, leading to a percent error of $\frac{.000900}{.0411} = 2.19\ \%$. What this slope is literally interpreted as is the time to drain over the diameter of the hole raised to the -3 power. This is also the time multiplied by the cubed diameter of the hole. But this graph shows that as the size of the hole increases numbers, the time decreases. This applies to fractional numbers because when a fraction is cubed, a smaller number results. With 1 over this smaller number, a larger number results. This is why the point at x-value 4096 actually represents the smallest possible hole. The smaller values on the x-axis represent larger hole sizes. The y-intercept on this graph represents when the whole is so large that there is basically no longer a whole. However, it is impossible to reach this stage because no matter how large the diameter of the hole is, 1 over the diameter of the whole cubed will never be zero. Therefore, there is no true y-intercept. This graph also shows that there is a great increase in time between the smallest hole and the other holes through the amount of units on the x axis and the distribution of the points. Because there was a constant increase in the size increments of the drill bits, there should have been constant spacing on the x0axis between the data points. However, because the curve fit shows that as the hole size increases, the time to drain decreases and the x-axis on the linear graph is an inverse cubic of the original x values, the spacing between the x-values on the x-axis is not constant.

Conclusion

According to the data, as the size of the hole increases, the time it takes for the can to empty decreases inversely. The y-intercept on the graph is the time it takes for the can to empty if there is not a hole in the can. For this reason, there is not y-intercept, but rather an asymptote. When deciding on the sizes, I chose the 1/16 inch in order to simulate the smallest possible hole in the can. This is why I saw the drastic increase in the time taken to empty. I believe that if I used any smaller drill bits, the can may not have even drained, as for this size only, there was a continuous drip, rather than a stream. If I were to increase the range of data, to include larger hole sizes, the graph would continue to approach 0 seconds. 0 seconds is also an asymptote because it is impossible for the time to be in the negatives. If the hole becomes large enough, the water would not go through the hole but instead fall through the can, as it could no longer retain water.

Evaluation

Some limitations to this experiment were the ways of releasing the water. Often during the experiment, water would spill out of the container through the top, rather than the hole, and that trial was not recorded. Also the data in the trial, in my opinion, became less accurate as the hole size increased. This is because the time it takes for the can to empty is so small that basically once the timer was started it needed to be stopped again. I feel as though the range of data was appropriate because any smaller hole sizes may have resulted in no drainage at all and any larger hole sizes would have led to fairly inaccurate data.

Improvements

Some improvements to be made include the timing system and the release system. If I had set up a camera to record each trial, I would be able to see the exact frames where the water started and stopped draining. This would have led to far more accurate data. Also, when releasing the water, it was hard to keep all the water inside the plastic wrap over the hole. Also, as I continued use of the plastic wrap, it started to hold some of the water in it instead of dumping the water into the can. I had to change the sheet of plastic every 3 trials. If I had found a better way to clog the holes, such as with rubber stoppers or corks with the same diameter as the holes, I feel as though the process of the experiment would have been facilitated. One more way to facilitate the process of the experiment would be to build a contraption to hold the container at the correct angle at all times. I believe that if I had nailed or screwed the container to a stable surface, such as a vertical board or tripod type stand, at the desired angle, the container would not have the ability to shift during the experiment. Although I measured the angle of the container with the horizontal before each trial, there is possibility that when I released the water, the container could have moved slightly. If I were to make this contraption, the data would become slightly more accurate along with a lesser time to complete the experiment due to the elimination of the need to re-measure the angle after every trial.