# The Imploders

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December 05, 2000

**Goals of the project:**

The purpose of this project was to analyze the implosion of aluminum cans. There are two primary parts. In the first part of this experiment, we wanted to obtain multiple-image photos that clearly defined the distance traveled by the can, within a given time interval. The second part involved analyzing the photos. We hoped to find the average acceleration of the can as well as the average force that caused this acceleration (ambient air pressure).

**Theory:**

We crushed our can using some basic Chemistry principles. We wanted to create a pressure difference between the inside and the outside of the can. To do this, we placed a small amount of $H_2O$ inside the can and then heated it until the $H_2O$ reached a boil. This caused the majority of the air to leave the can and replace it with $H_2O$ vapor. The reason the can does not crush at this stage is because the force of the $H_20$ Vapor on the can's wall is equal to the outside pressure (14.7lbs/in/in). The gas rapidly expands to occupy the same space as the air that was driven out once occupied. When the can is submerged inside the ice-bath, the expanded $H_2O$ vapor quickly condenses but the temperature inside the can does not significantly change. As the vapor condenses the pressure difference increases because the $H_2O$ vapor no longer is pounding against the can's wall. The $H_2O$ vapor condenses into a $H_2O$ liquid, which results in a decrease in volume because liquid occupies less volume than gas. The ideal gas law does not apply here because although the volume inside the can decreases, the pressure does not decrease. Because the can is under $H_2O$ liquid, no new gas can occupy the volume that the $H_2O$ vapor once occupied. The outside forces pushed throughout the can and thus causes it to implode.

**Equipment and Techniques:**

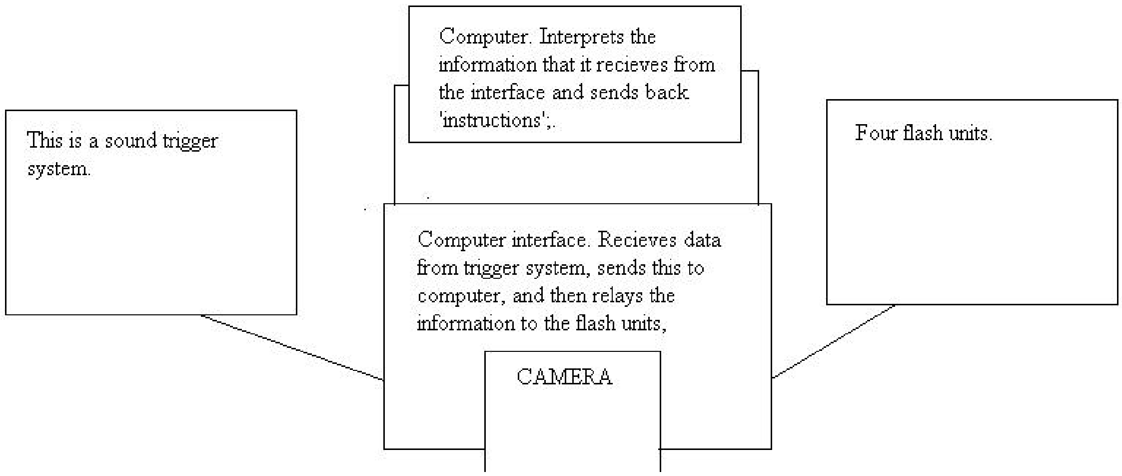
This project included two parts in which two different setups had to be made. The first was the image capturing setup and the second was the actual imploding cans experimental setup. For convenience all of our materials were placed on a small mobile cart.

<u>Image Capture Setup:</u>

In high speed imaging the basic idea behind taking a photo, is that originally one is in the dark with the camera shutter open. When the desired event is occurring a light source goes off and exposing the film media thus capturing the image. For this experiment it was necessary to obtain a multiple image photo. This means that more than one image are super-imposed on each other on a single frame. To do this, the same technique was used but more than one flash goes off as the shutter is open resulting in multiple images on a single frame.

The setup was created by Dr. Winters and his former student (Footnote 1). It allows the user to control how many flashes are going to be used, the interval time between each flash and the delay time of the initial flash.

Explanation using Diagram

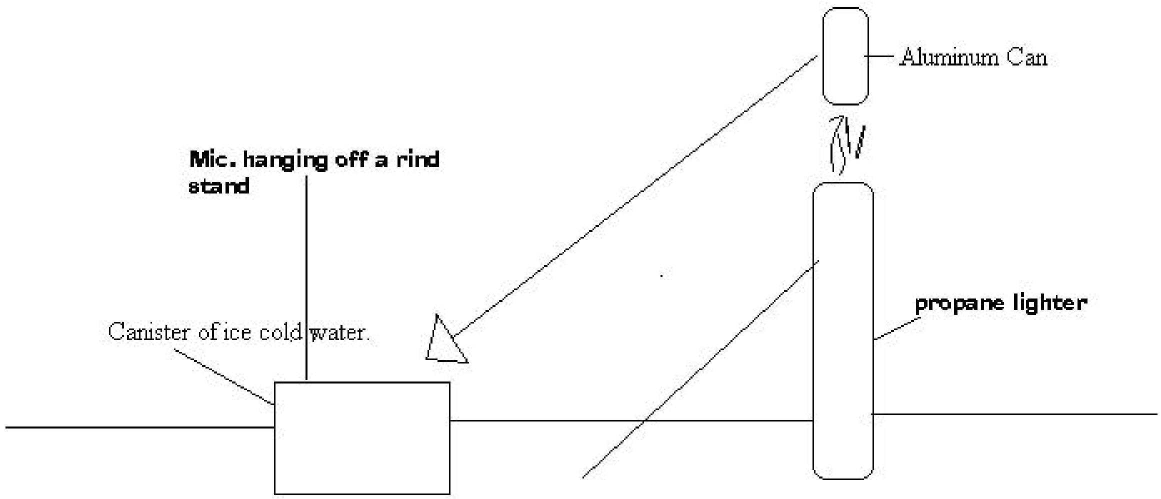



In this system, a sound trigger system senses a sound and creates a signal and sends this signal to the interface. The interface then sends this message to the computer, who according to the user's settings (number of flashes, interval time, and delay time), sends a message back to the interface. This message is then relayed to the flash units that are then set off. The whole time this is happening, the camera's shutter is open and is being exposed to the light.

Experimental Setup:

In this part of the experiment, we tried to create a pressure difference between the inside and the outside of the can. As said in the theory section, we did this by driving out the air, replacing it with water vapor, and the inverting the can in cold water. The water vapor then condensed and the pressure difference was made.

Diagram of Setup




(Note: we initially started with a laser to trigger the flashes but this did not work. We discovered that the laser would not trigger the flash in time so we had to switch to a sound trigger.)

Together:

The cart consisted of a Toshiba laptop, four flash units (Vivitar 283's), and a trigger system. We used a special program called Intervalometer that Dr. Winters and a former student had programmed[1]. The program enabled us to set a delay time for the first output. This time was set on a minimum time of .0016 ms. We then set an interval time for our other three outputs ranging from 2.5 ms to 5 ms. We used a sound trigger to set of the four flashes. We hung a microphone from a ring stand that was positioned close to the imploding can. The four flashes were lined up in a successive row, and they each had a different color filter on the flash in order to differentiate the different frames in the images. We heated the soda can with propane lighter until the water started to boil from the top of the can. We then inverted the soda can using tongs into a plastic box that was filled with some cool water and the sound trigger was triggered immediately after the can started to crush. We had some trouble seeing the plastic box when the lights were off, so we eventually started to use a flashlight

Both of the setups worked came together quite well. The flashes and the camera were placed in front of the experimental setup. We used two different cameras: the Olympus C3000 and the Nikon Cool-Pix 990.

[1] Chris Hectins, a former student of Dr. Winters High Speed Imaging class created the Intervalometer program.

As you can see, then, the shutter speed is taken right out of the picture. The way to change the exposure of the film is either to adjust the aperture, the flash duration, or even the film speed. When we were shooting we found that by lowering the film speed to 100 and capturing the image. For the Nikon we used an aperture of 2.8 and the for the Olympus we used an aperture of 5.0 primarily.

**Data:**

Constants for frame counts 1-19:

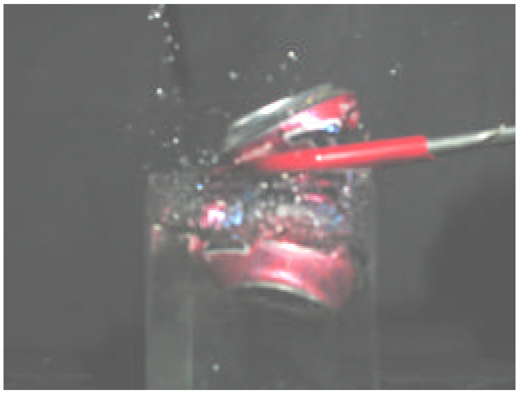
- ISO: 100
- Flash to can distance: .30m
- Trigger (microphone) to can distance: .03m
- Camera to can distance: .25m
- Delay time: .0016ms
- Mass of typical Can: .0040 kilograms
- Radius of the Can: 3.25 centimeters
- Filter Order: Red, Blue, Orange, Green
  - Delay time: period of time for first flash to go off
  - Interval time: period of time between the first and second flashes which equals period between second and third flashes which equals period between third and fourth flashes.

Data Table:

| Frame Count | f-stop | Shutter | Focal length | Image Resolution | Interval Time (ms) | Filename | Subject Description |
|---|---|---|---|---|---|---|---|
| **Nikon**1 | 2.8 | bulb | 2 | Normal | 29.99 | Cans1090.jpg | white/red blur |
| 2 | 2.8 | bulb | 2 | Normal | 5.999 | Cans1095.jpg | 3 distinct images |
| 3 | 2.8 | bulb | 2 | fine | 5.999 | Cans1101.jpg | fine resolution 4 flash |
| 4 | 2.8 | bulb | 2 | Normal | 5.999 | Cans2121.jpg | red, blue, orange flashe |
| 5 | 2.8 | bulb | 2 | Normal | 5.999 | Cans2124.jpg | good pic, 3 flashes |
| **Olympus**6 | 2.8 | bulb | 2 | 5HQ | 5.999 | Cans3003.jpg | red |
| 7 | 2.8 | bulb | 2 | 5HQ | 5.999 | Cans3004.jpg | orange |
| 8 | 2.8 | bulb | 2 | 5HQ | 5.999 | Cans3005.jpg | blue |
| 9 | 2.8 | bulb | 2 | 5HQ | 5.999 | Cans3006.jpg | green |
| 10 | 5.6 | bulb | 2 | 5HQ | 3.999 | Cans3008.jpg | coke can |
| 11 | 5.6 | bulb | 2 | 5HQ | 3.999 | Cans3009.jpg | white can |
| 12 | 5.6 | bulb | 2 | 5HQ | 4.499 | Cans3010.jpg | blank |
| 13 | 5 | bulb | 2 | 5HQ | 3.499 | Cans4002.jpg | good pic |
| 14 | 5 | bulb | 2 | 5HQ | 3.999 | Cans4003.jpg | crushing from right |
| 15 | 5 | bulb | 2 | 5HQ | 3.999 | Cans4004.jpg | didn't crush as well |
| 16 | 5 | bulb | 2 | 5HQ | 3.799 | Cans4005.jpg | reflection |

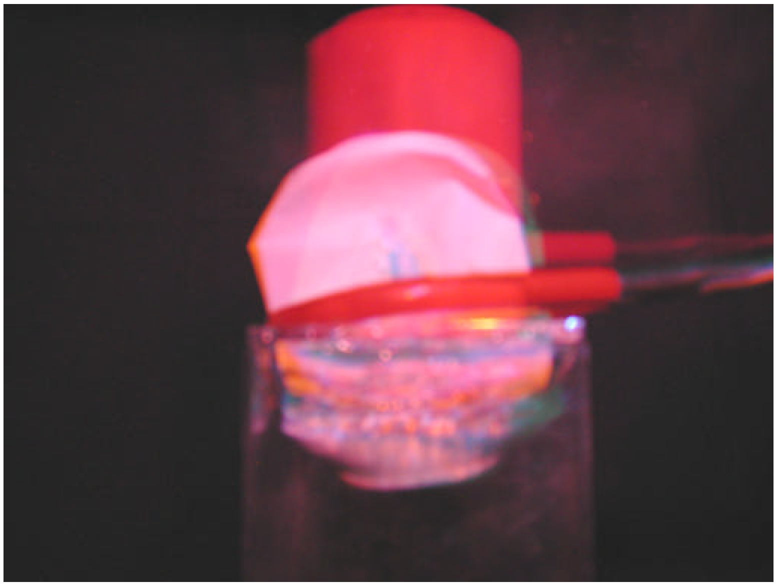
| | | | | | | | |
|---|---|---|---|---|---|---|---|
| 17 | 5 | bulb | 2 | 5HQ | 3.799 | Cans4006.jpg | curving reflection |
| 18 | 4.5 | bulb | 2 | 5HQ | 3.799 | Cans4007.jpg | increased exposure |
| 19 | 5 | bulb | 2 | 5HQ | 3.999 | Cans4008.jpg | good separation |
| 20 | auto | auto | auto | 5HQ | 3.999 | Cans4009.jpg | fun shoot (pile of cans) |

<u>Data Descriptions</u>



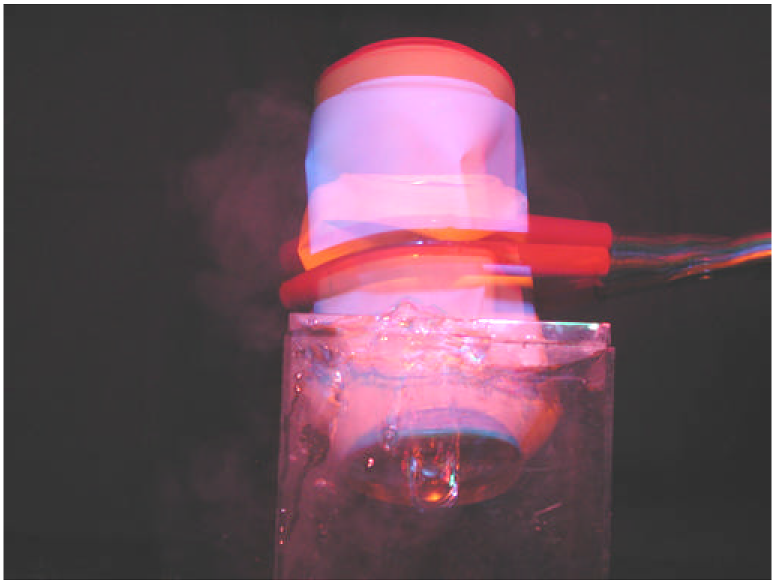
CANS1089.jpg

We initially started taking pictures using unpainted cans to get the timing of the can implosion. However, we had a difficult time differentiating between the successive frames since there was no background color to distinguish between the different colored flash units. The picture above represents the pictures we got when we did not use a white can.



CANS1090.jpg

Our first picture using a white can was not desirable because three of the flashes went off after the can already had crushed, so we decided to decrease the interval time between the flashes; we were hoping to catch a high speed image of the can when it initially started crushing to when it ceased crushing. We wanted to get successive frames of the image and we also wanted a successive contrast in colors, which did not happen in this picture above. Our immediate delay (1st flash) was .0006ms and our interval time (for 3 flashes) was 30 ms. All of this data can be referenced by matching the filename of the photograph with the data table above.



CANS1095.jpg

We had four flashes: red, green, blue, and orange; in this picture our interval time was significantly decreased to 5.999ms. We examined our second picture on Dr. Winter's computer, and we had a hard time seeing the second flash: green color. Therefore, we decided to take pictures of the individual flashes on a white can to determine what color each flash was giving off.

Green on Nikon

CANS1096.jpg

We discovered that the green color flash was actually giving off a bluish image on the can. We perhaps thought that changing the resolution would affect our image colors. We took another image keeping everything the same except changing the resolution from normal to fine. The picture color did not change. We learned that changing the resolution on the Nikon did not change the color of the flash in the picture. Dr. Winters suggested that we take out our green flash and just go with three outputs.

CANS1101.jpg

cans2124.jpg

We also discovered that the way we held the can affected the way the can crushed. Sometimes we did not hold the can fully submerged in the water. Consequently, the crush of the can was quite different. Side by side comparison of these two pictures (cans 101.jpg and cans2124.jpg) indicates two of the many different ways that the can imploded.

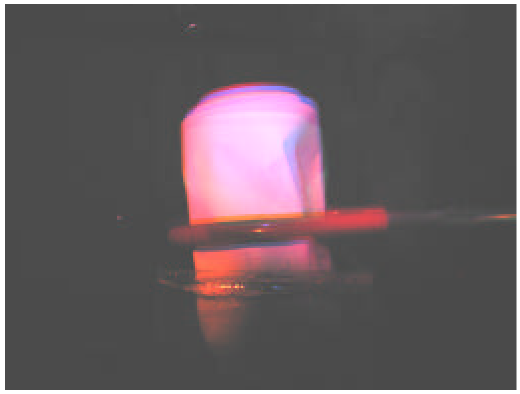
cans2124.jpg

In this picture, we made sure to hold the can so that it was fully submerged in the water. The outcome was successful and we got pictures of the can using three outputs (red, blue, and orange). The picture had all three distinct colors in successive frames of the can crushing. This is one of our better pictures.

Green on Olympus

cans3006.jpg

When started to use Rob's Olympus Camera starting with our sixth imploding white can picture. We took pictures of individual flashes to see how Rob's camera would display the filter flash colors. Rob's camera (Olympus) displayed the green filter as green color in the above photo (cans3006.jpg).



cans4003.jpg

We switched the outputs from three to four ( red, blue, orange, and green). We decreased the interval time to 3.999ms and got a decent picture. We took a number of pictures using four flashes (red, blue, orange, and green) with time intervals varying from 3.5ms-4.5ms. The pictures all look similar to cans4003.jpg. The reason for this is that for the last group of photos that we took, we had switched to Rob's camera. Rob's camera did not distinguish between the flash colors in a single frame very well as seen in the above photo; consequently, our photos were not as desirable as cans2124.jpg, which was taken with the Nikon.

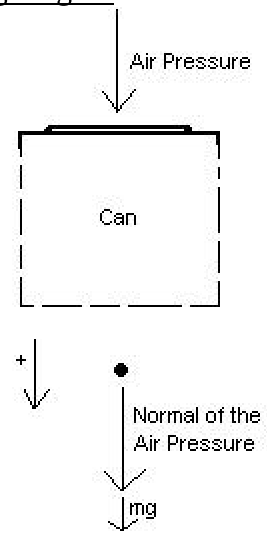
**Analysis:**

Velocities : (Method Example in appendix 1).

| Picture (filename) | Velocities (m/s) | Regression Line | Slope =average acceleration |
|---|---|---|---|
| Cans1095.jpg (amit) | .506, 1.59, and 5.63 | Y=427x-1.27 | 427m/s/s |
| Cans3009.jpg (amit) | .671 and 1.98 | Y=327x+.0165 | 327m/s/s |
| Cans1095.jpg (rohit) | .61, 1.36, and 5.29 | Y=390x-1.09 | 390m/s/s |
| Cans4006.jpg (rohit) | .841, 1.00, and 9.45 | Y=1150x-2.6 | 1150m/s/s |
| Cans3009.jpg (rob) | .600 and 2.20 | Y=400x - .2 | 400m/s/s |
| Cans4008.jpg (rob) | .350, 1.40, and 4.10 | Y=470x - .86 | 470m/s/s |

Examination of our average accelerations indicates that most of them fall between 320-470 m/s/s. The one outlier is for Cans4006.jpg which yielded a value of 1150 m/s/s because the can crushed slightly initially and then crushed drastically by the next flash, resulting in a greater average acceleration. Excluding our outlier, we get an average of the average accelerations to be 402.8 m/s/s.

Analysis using Diagram




If we assume that the air pressure is the only force acting on the part of the can in bold, we can isolate that part of the can and do a simple force problem.

$$F_{net} = N + mg = ma$$
$$N = ma - mg$$
$$N = (.0040\ kg)(400\ m/s/s) - (.0040\ kg)(9.8\ m/s/s)$$
$$N = 1.6\ Newtons$$

The remaining calculations are just conversions and simple mathematics:

The surface area of the can = $radius^2(pi)$
Surface area = $(.0325\ m)^2(3.14)$
Surface area = $3.3 \times 10^{-3}\ m^2$

Air pressure = force/surface area = (1.6 Newtons)/($3.3 \times 10^{-3}\ m^2$)
Air pressure = 490 Pascals

Conversion from Pascals to psi = Pascals/Conversion factor
(490 Pascals)/($6.894 \times 10^3$ Pascals/psi) = .071 psi

Percent difference from accepted value:
((14.7 psi)-(.071 psi))/(14.7 psi)*100 = 100% difference

**Discussion of Results:**

We calculated a value for air pressure based on our experiment and compared it to the accepted value for air pressure. Our value was .071 psi, yielding a 100% difference. The most likely source of discrepancy in this experiment involved our force equation. To complete this analysis, we needed to assume that air pressure and gravity were the only forces on the bottom of the can. However, the bottom of the can is supported by the midsection of the can. This causes us to get a lower value for the air pressure because the bottom of the can does not accelerate as fast as it would have if it were alone. In addition, we were not able to create a total vacuum inside the can. There is still a slight air pressure exerted by water vapor inside the can that counteracts the force of the outside air pressure. This also results in a smaller value for the air pressure.

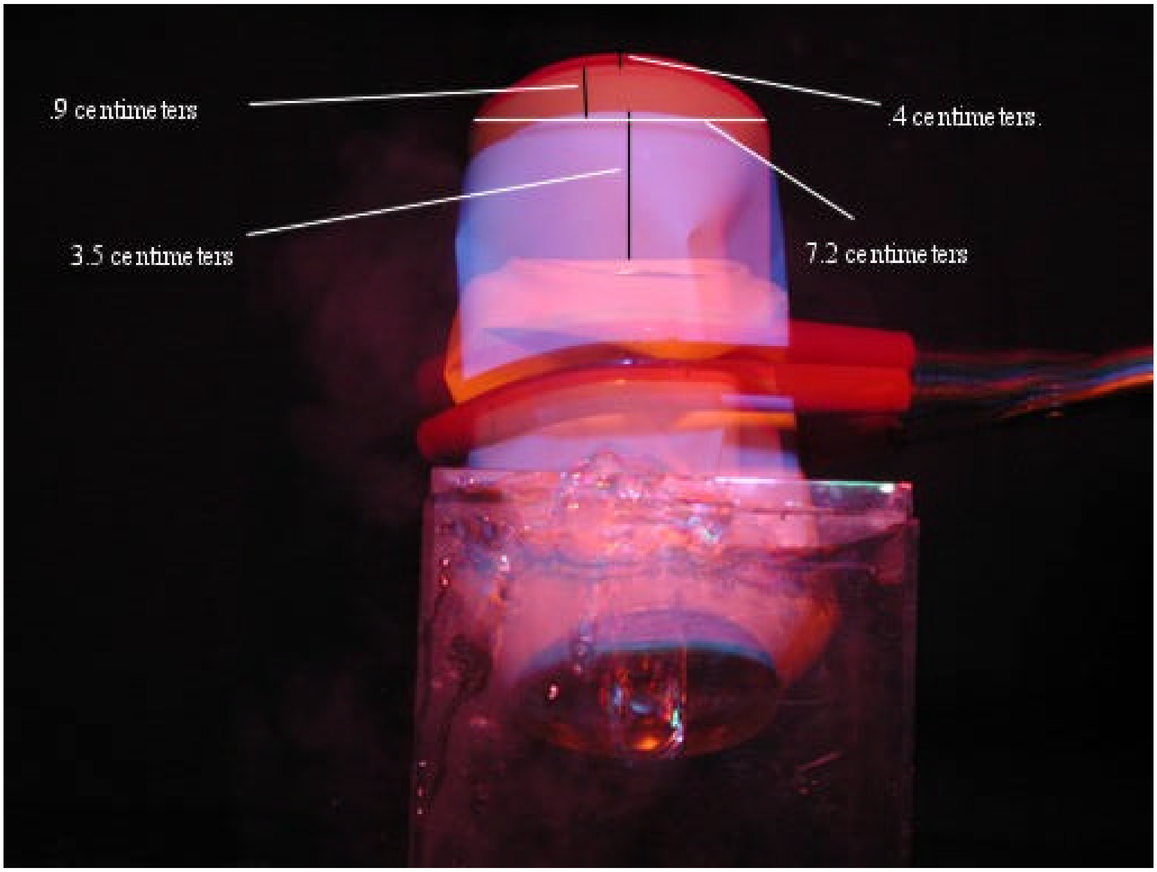
**Conclusions:**

We used high-speed imaging techniques and physics to calculate a value for the ambient air pressure. We were able to acquire high-quality images of the imploding aluminum cans. We were also able to calculate a value for the ambient air pressure. However, we were unable to reduce the amount of error significantly enough to result in a value close to the accepted value. The value we experimentally determined was roughly half the accepted value. Event though our values yielded a high percent error, we still met the objectives of our project. We took a number of pictures and probably would have yielded more aesthetically pleasing pictures if we continued to use the Nikon camera. We successfully analyzed the photographs for the average acceleration and average force values, which were the goals of our project.

**Bibliography:**

1.High Speed Photography with Computer Control By Dr. Winters, Loren M.

Appendix : How we got the velocities.




Scale : Actual Length/ Length on paper
6.54cm/7.23 cm = .9083

Velocities: In this case there are three different velocities.

Velocity 1:

Distance1: length on paper * scale: .4 cm * .9083 = .0036332 meters
Time interval: .0059989 seconds
Velocity = distance / time: .0036332meter/.00599898seconds = .61 meters/second

Velocity 2:

Distance1: length on paper * scale: .9 cm * .9083 = .008147 meters
Time interval: .0059989 seconds
Velocity = distance / time: .008147meter/.00599898seconds = 1.36 meters/second

Velocity 3:

Distance1: length on paper * scale: .3.5 cm * .9083 = .031297 meters
Time interval: .0059989 seconds
Velocity = distance / time: .031297 meter/.00599898seconds = 5.29 meters/second