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Investigating Collisions in One Dimension: The Relationship between Mass and Sound

Research

The aim of the experiment is to investigate the relationship between mass and sound produced in a one-dimensional collision between a wooden trolley and a wooden surface. This will be done

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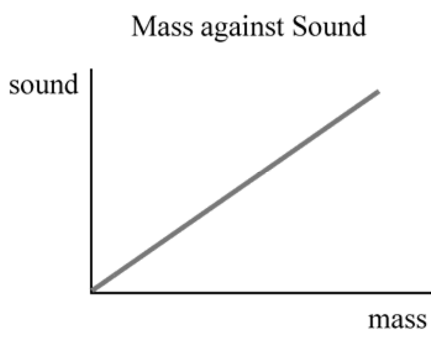
by changing the mass of a trolley, and then recording the collision sound by using a microphone and an oscilloscope.

The trolley will always roll down a runway the same distance and from the same initial height, hence it should collide with the same speed each time. The theory of kinetic energy says that kinetic energy is proportional to the square of the speed (which should be a constant) and proportional to the mass. Hence as the mass increases kinetic energy increase. All the kinetic energy is lost in the collision, mostly due to heat but also to sound. Assuming that the percentage of energy changed into sound is the same for all collisions, then I predict that as the mass increases so the sound will increase. This is a directly proportional and linear relationship. The ideal graph is sketched below.



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Variables

- The independent variable is the mass of the trolley
- The dependent variable is the sound intensity measured in arbitrary units (squares on the cathode ray oscilloscope)
- The controlled variables include the acceleration of gravity, the height of the inclination of the ramp, the trolley and microphone positions, surface of impact.

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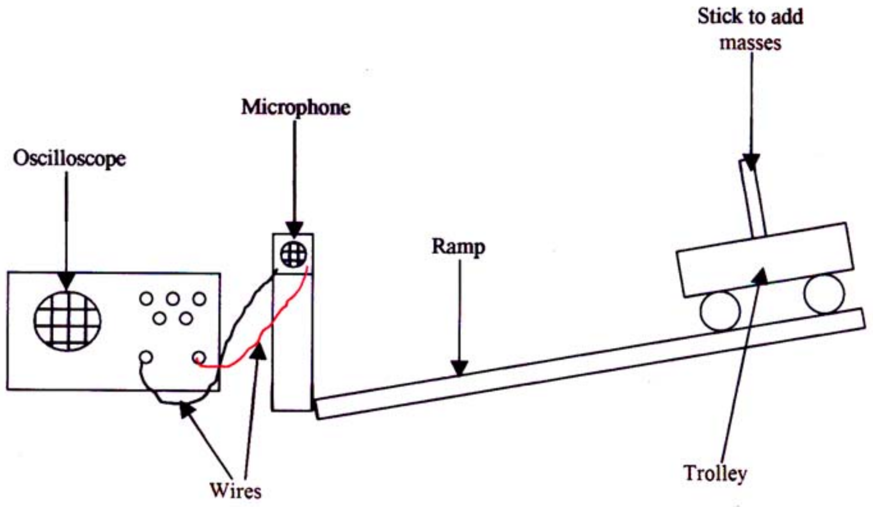
Apparatus

- Trolley
- Wooden ramp
- Wooden block
- Ruler
- Nine 10 gram (0.010 kg) masses
- Microphone to record the sound
- Oscilloscope to show the peaks of the sound
- Wires
- Camera to record the peaks of sound
- Tripod to hold the camera

Diagram of Experiment



D 2 A camera was put in front of the oscilloscope to record the highest peak registered with the microphone.

Method

- Set the apparatus as shown in the diagram.
- Set a height of 30.0 cm for the ramp, and keep it constant for the whole experiment.
- Set the distance of the microphone to 5.0 cm from the point of collision and keep it constant for the whole experiment.
- Start recording wit the camera.
- Record the sound of the first collision without additional masses

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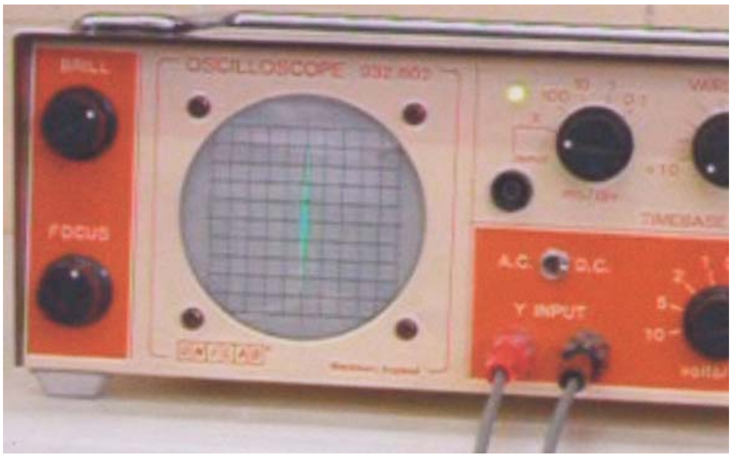
- Add 10 grams and record another collision.
- Do this process until 90 g are reached.
- Repeat the process until three consistent results appear to reduce errors, and then an average of the result is taken.



This is a screenshot of what the camera recorded and it can be seen where the highest sound peak is.

Each square on the screen of the CRO is one unit.

The mass M is the mass added to the trolley, and so does not include the trolley itself.

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Data	Sound S / arbitrary units ±0.5 units			
Mass M / kg ±0.001 kg	1st trial S_1	2nd trail S_2	3rd trial S_3	Average Sound S_{ave} / units ±0.5 units
0.000	0.5	1.0	0.5	0.7
0.010	1.0	1.0	0.5	0.8
0.020	2.0	1.5	2.0	1.8
0.030	2.0	2.5	1.5	2.0
0.040	2.5	3.0	2.5	2.7
0.050	3.0	3.5	3.0	3.2
0.060	3.5	3.5	3.5	3.5
0.070	3.5	4.0	3.5	3.4
0.080	4.5	5.0	4.5	4.7
0.090	4.5	5.5	5.0	5.0

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The average of three sound measures is, e.g., $S_{ave} = \frac{S_1 + S_2 + S_3}{3} = \frac{1.0 + 1.0 + 0.5}{3} \approx 0.8$

Mass Uncertainty

The mass of the trolley is not relevant here, so we can ignore its uncertainty. The uncertainty in the added masses is ±0.001 kg. This is determined by the significant figures given on the mass set.

Sound Uncertainty

Because I read the sound units from a video of the CRO it is not easy to determine the uncertainty because the green line is faint and thin, so I will say that at its worst, the uncertainty in sound level is ±0.5 units. This is carried through to the average of the sound.

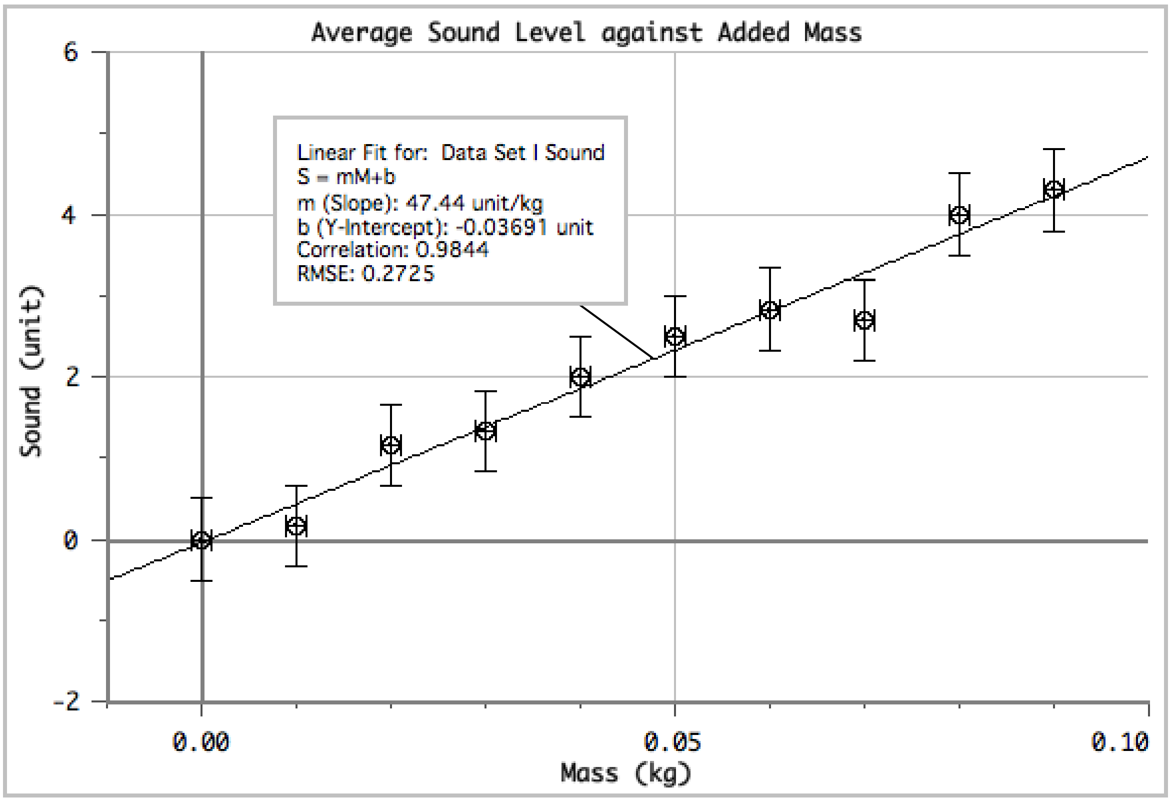
Graph of Data

My data for drawing a graph is then adjusted so that it can pass through the origin. To do this I substract the sound level for zero mass, which on average of 0.5 units; this means that the mass of the trolley is substracted from the total, such that the sound level due to added masses is now equal to $S_{mass} = S_{mass+trolley} - S_{trolley} = S_{mass} - 0.67\,\text{units} \approx S_{mass} - 0.8\,\text{units}$.

DCP 2

Data For Graphing	
Mass M / kg ±0.001 kg	Average Sound Due to Added Mass $S_{ave\ (added\ mass)}$ / units ±0.5 units
0.000	0
0.010	0.2
0.020	1.2
0.030	1.3
0.040	2.0
0.050	2.5
0.060	2.8
0.070	2.7
0.080	4.0
0.090	4.3

DCP 3



The gradient of the graph is 47.44 units per kilogram. The graph is linear and proportional and all the data points lie on the best straight line (as constructed by the computer).

Next, I calculate the uncertainty in the graphing results.

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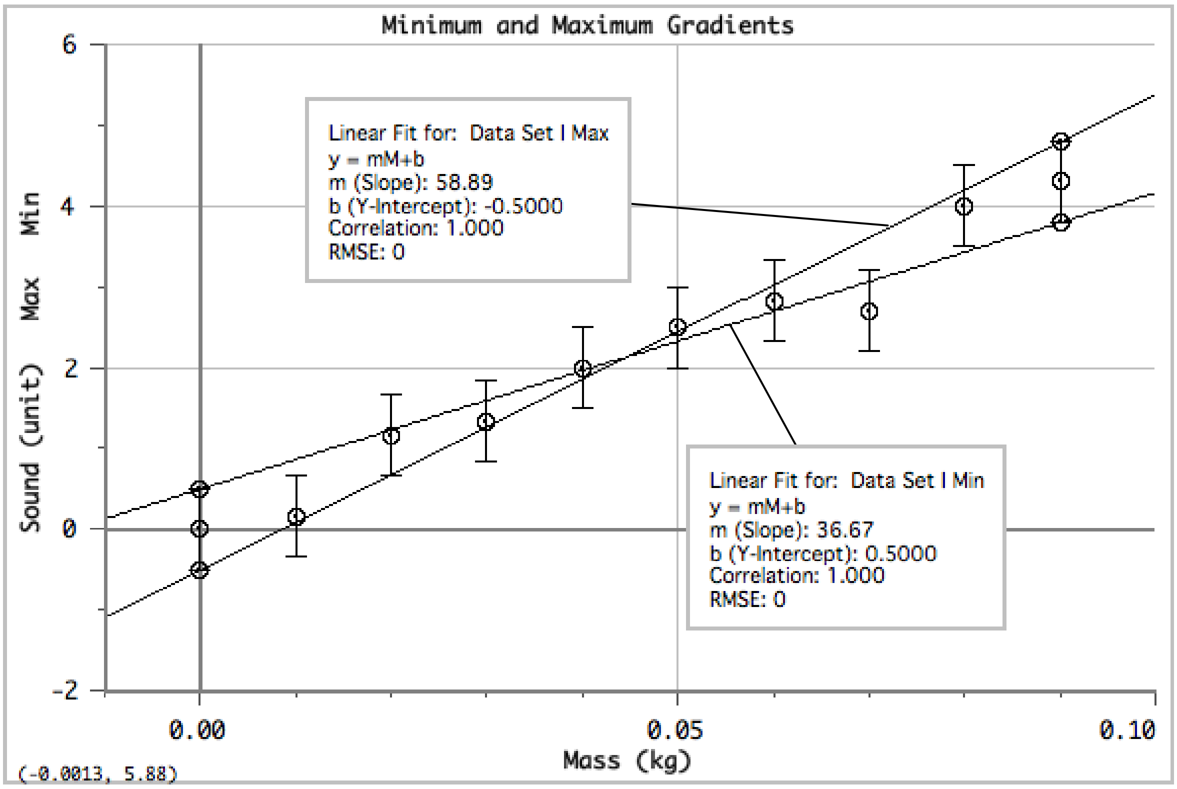

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The maximum gradient is 58.89 and the minimum gradient is 36.67. Again, the best-straight line gradient is 47.44.

The uncertainty **above** the best straight line is 58.89 – 47.44 = + 11.45.

The uncertainty **below** the best straight line is 36.67 – 47.44 = – 10.77.

The **gradient and its uncertainty** are thus 44.77 (+11.45)/(–10.77) or about 45 ± 11 to 2 SD.

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Conclusion

The gradient and its uncertainty means that the sound increases as the mass increases by a proportionality factor of about 45 units of sound per kilogram of mass, with an uncertainty of ±11 units of sound per kilogram.

As shown by my graph, there is a linear and proportional relationship between mass and sound produced in a collision, and by original research question has been answered with a reasonable degree of certainty. The original suggestion about sound and kinetic energy seems to justify my results.

Evaluation

CE 2

Even though the relationship is linear, it can be seen that the errors involved are significant. The gradient varies by about 24%, which is high. The error is mostly due to the precision that the peak sound is recorded. In fact, the peak sound registered in the oscilloscope was recorded with a camera, and it was very hard to see what was recorded in the fraction of second where the sound was at its highest value. The green line was light and thin at the peak.

Other errors occurred because the trolley did not go straight but tended to go to the left or right, meaning that the collision occurred at an angle and not perpendicularly. Other smaller errors were given by external sounds.

Improvements

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One improvement to make would be to use an oscilloscope that would record the highest peak as an actual value and show it. Perhaps a computer based CRO where data is sorted and where measurements are a high degree of precision. The CRO used for this experiment was very imprecise.

Another improvement would be to use a ramp that would be as wide as the trolley so that it will only go straight and not either left or right. However there will be another problem with this, which is that more friction will be present between the sides of the ramp and the trolley, but it does not matter because it will be the same throughout the experiment. Finally, other errors could be avoided by doing the experiment in an isolated room without external sounds affecting the entire experiment; otherwise a less sensitive microphone could be used.