5. Collision

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Problem

"A highly elastic Super Ball collides with a rigid surface. How can one determine the collision time? Propose various techniques and compare the experimental results."

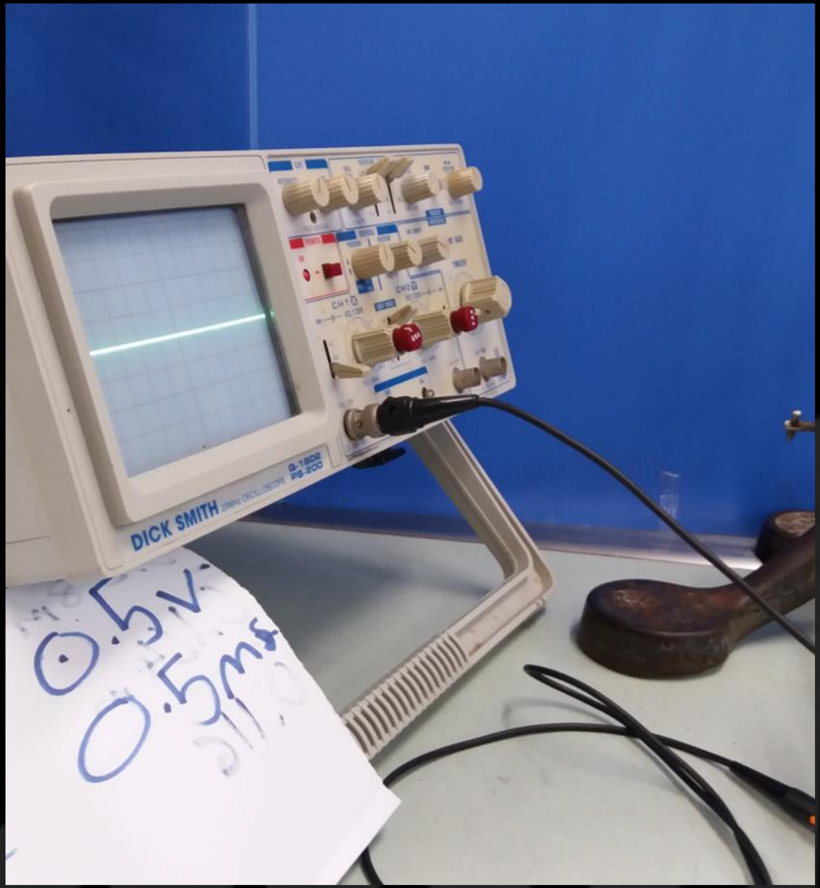
Different methods of testing

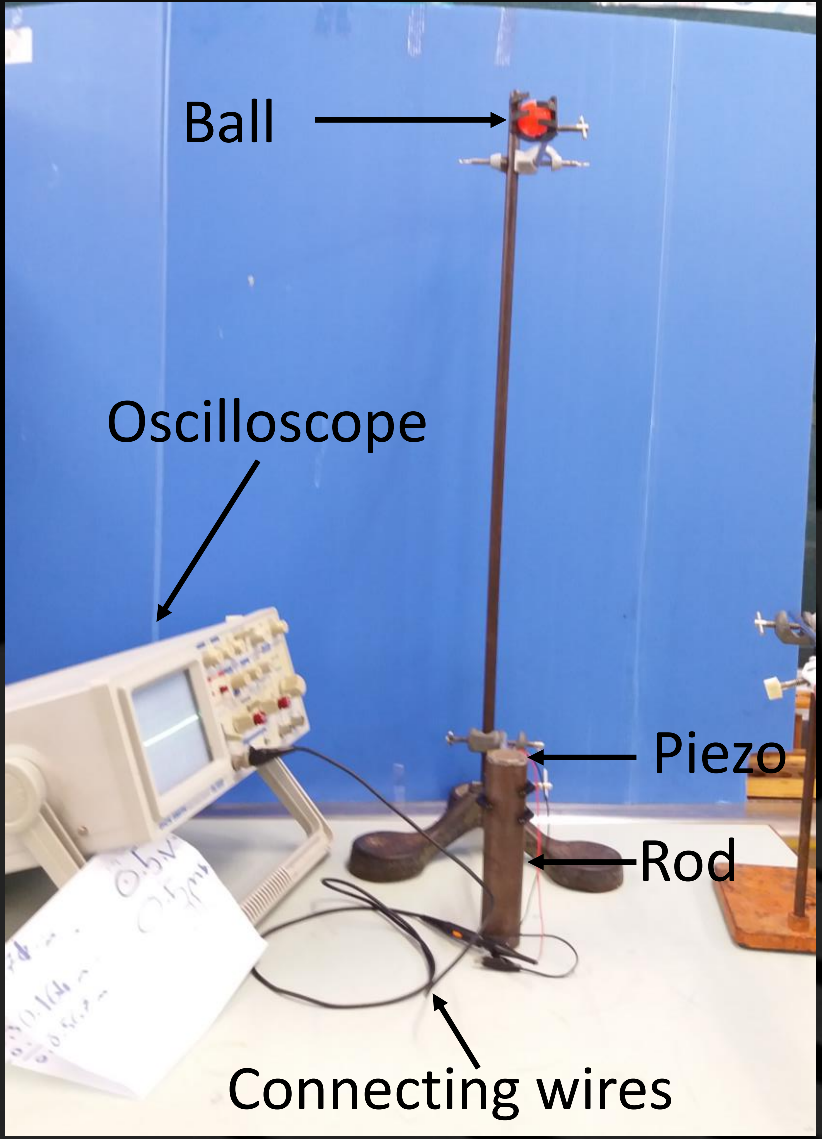
- High speed video
- Piezo disk– Voltage over time
- Sound
- Motion sensor

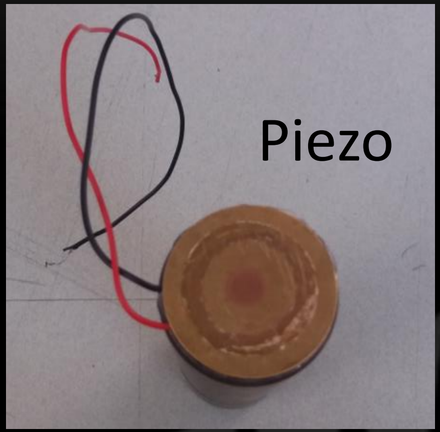
Big Ball
0.075kg

Small Ball
0.01kg

Piezo chip:

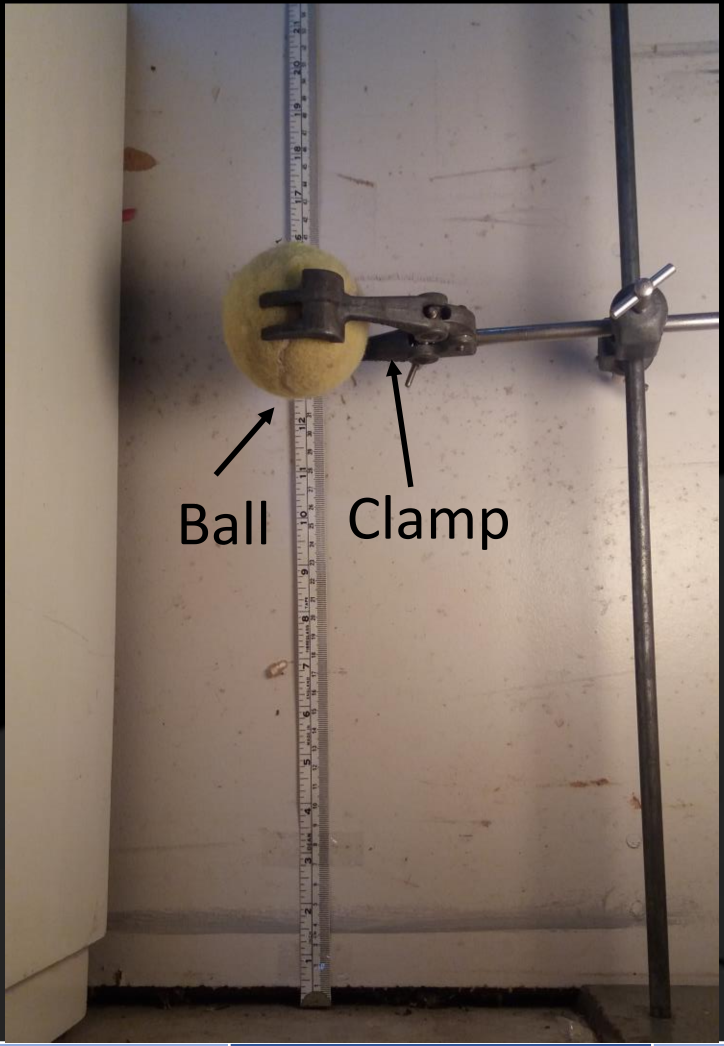

DICK SMITH
0.5V
0.5ms

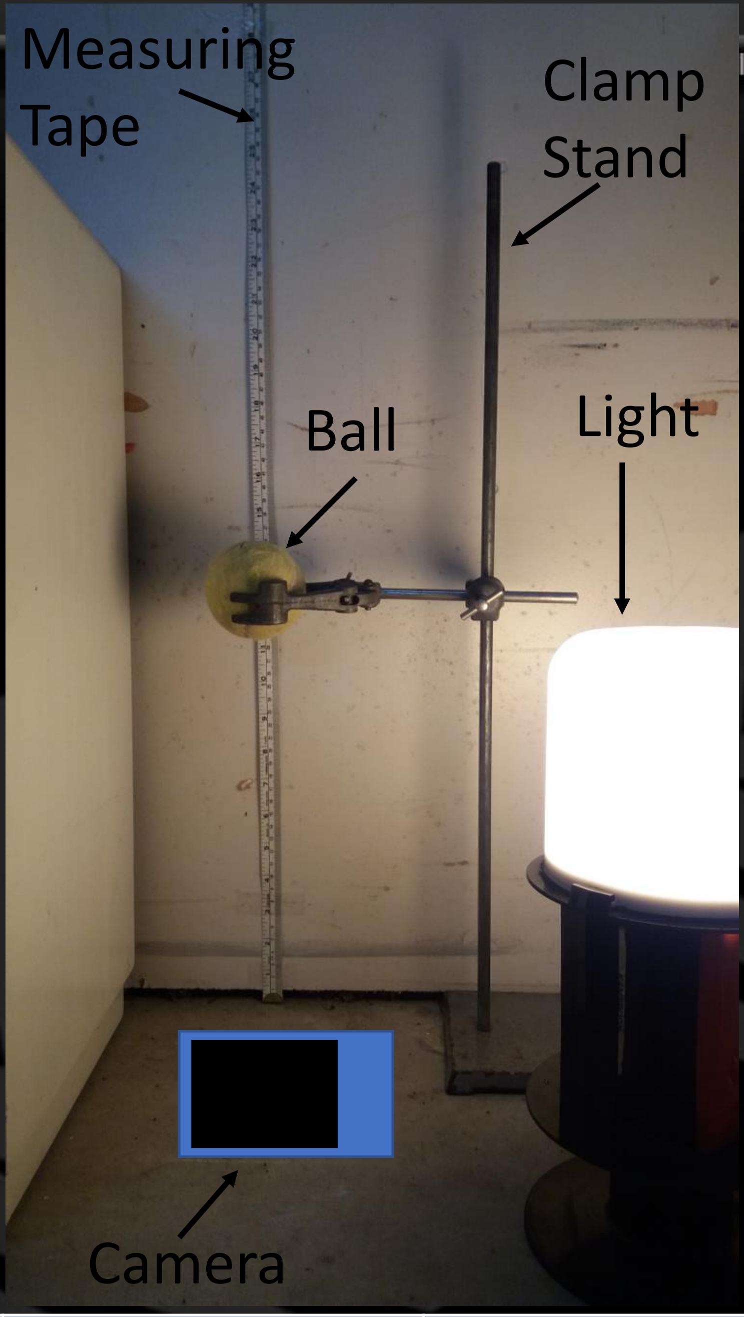

Ball
Oscilloscope
Piezo
Rod
Connecting wires


Piezo

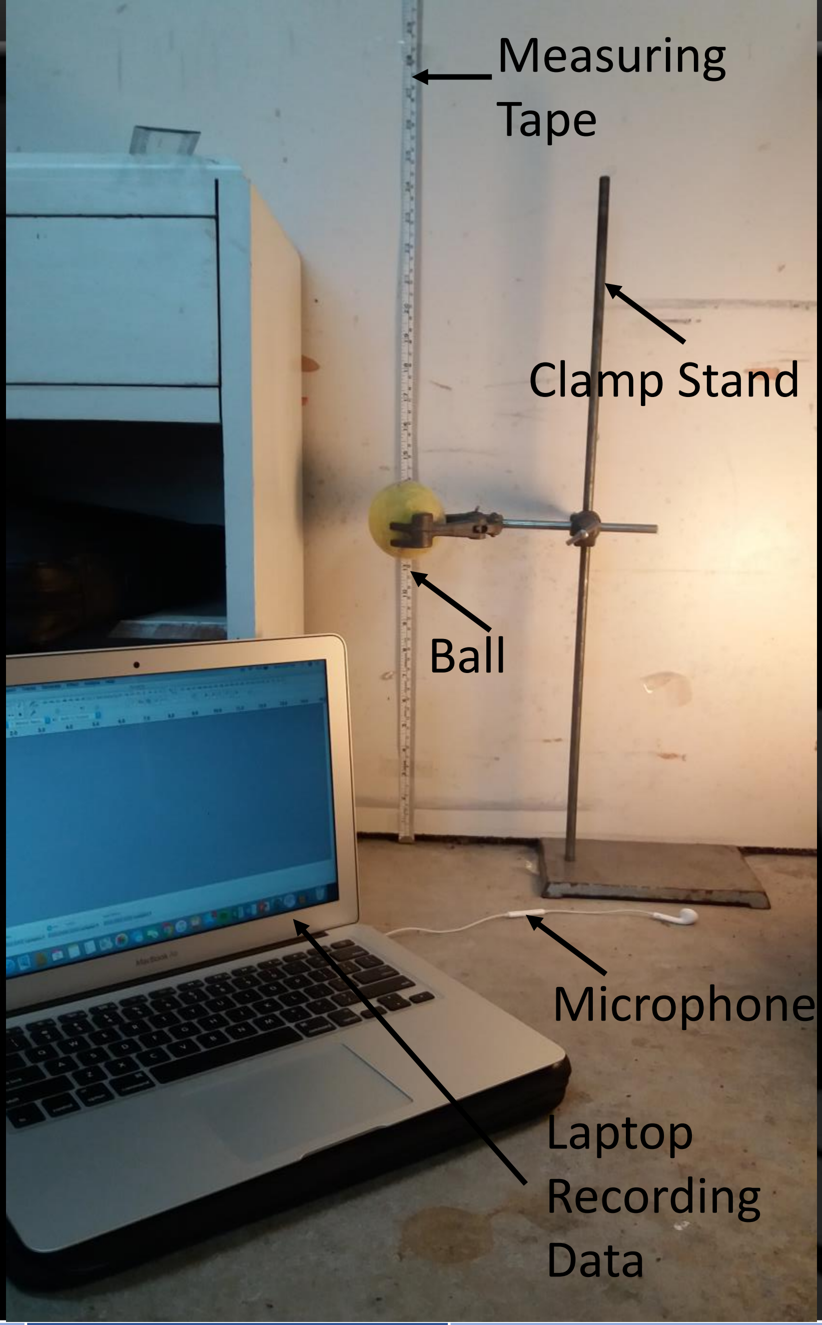

Rod

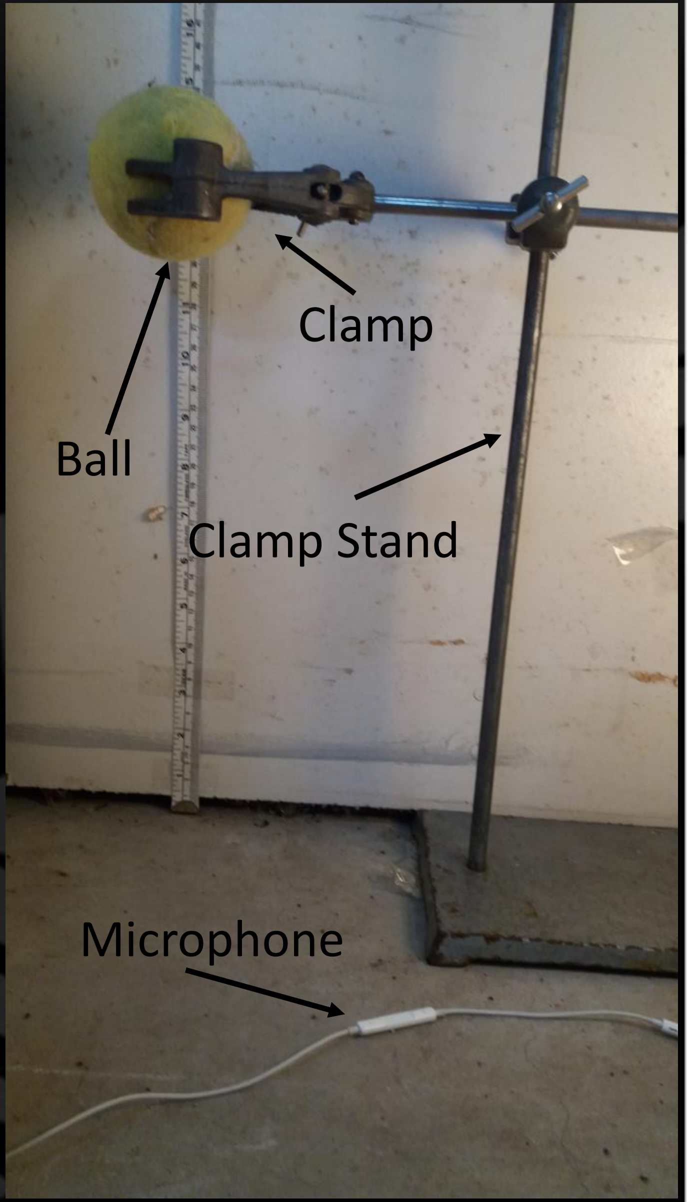
High Speed Video:



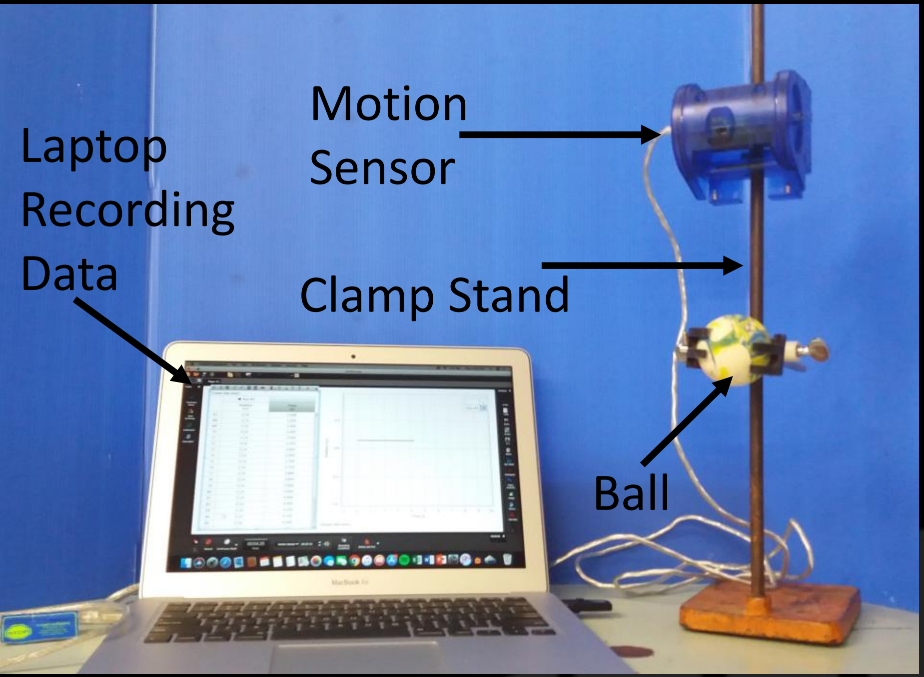


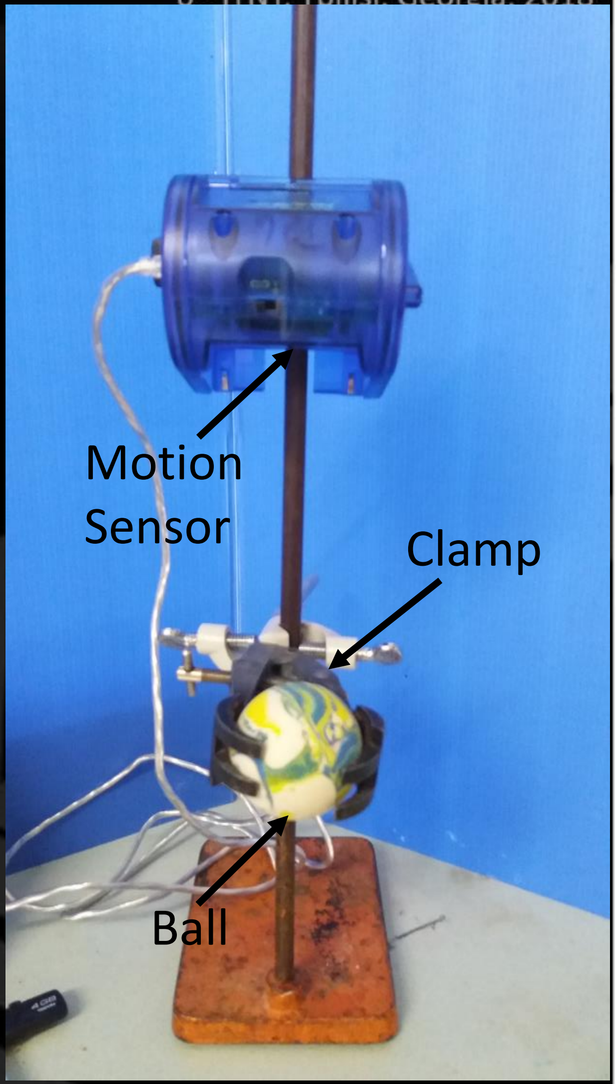
Sound:

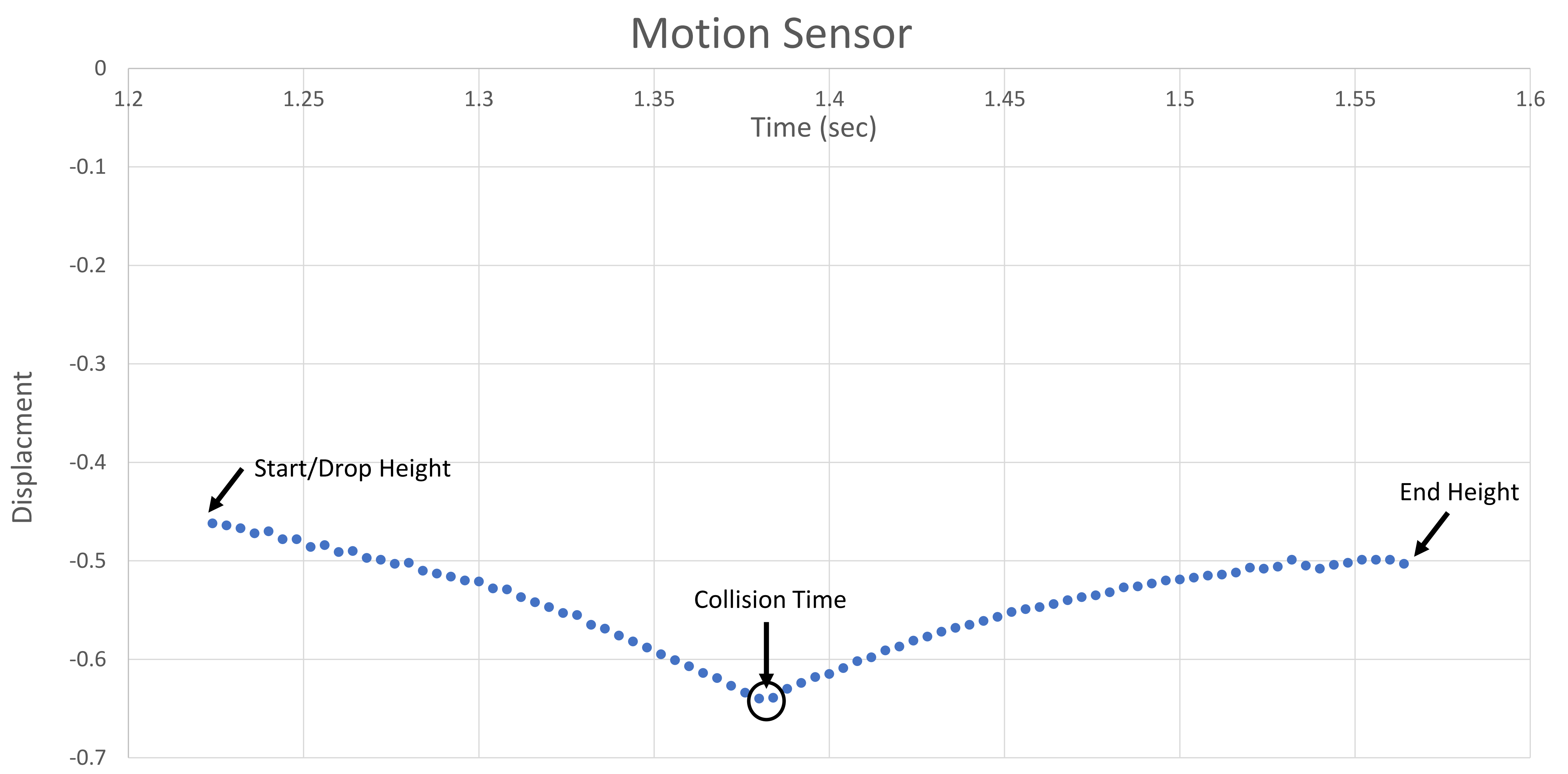

Measuring
Tape
Clamp Stand
Ball
Microphone
Laptop
Recording
Data


Clamp
Ball
Clamp Stand
Microphone

Motion Sensor:






Motion Sensor
Time (sec)
Displacment
0
-0.1
-0.2
-0.3
-0.4
-0.5
-0.6
-0.7
1.2
1.25
1.3
1.35
1.4
1.45
1.5
1.55
1.6
Start/Drop Height
Collision Time
End Height

What methods work best?

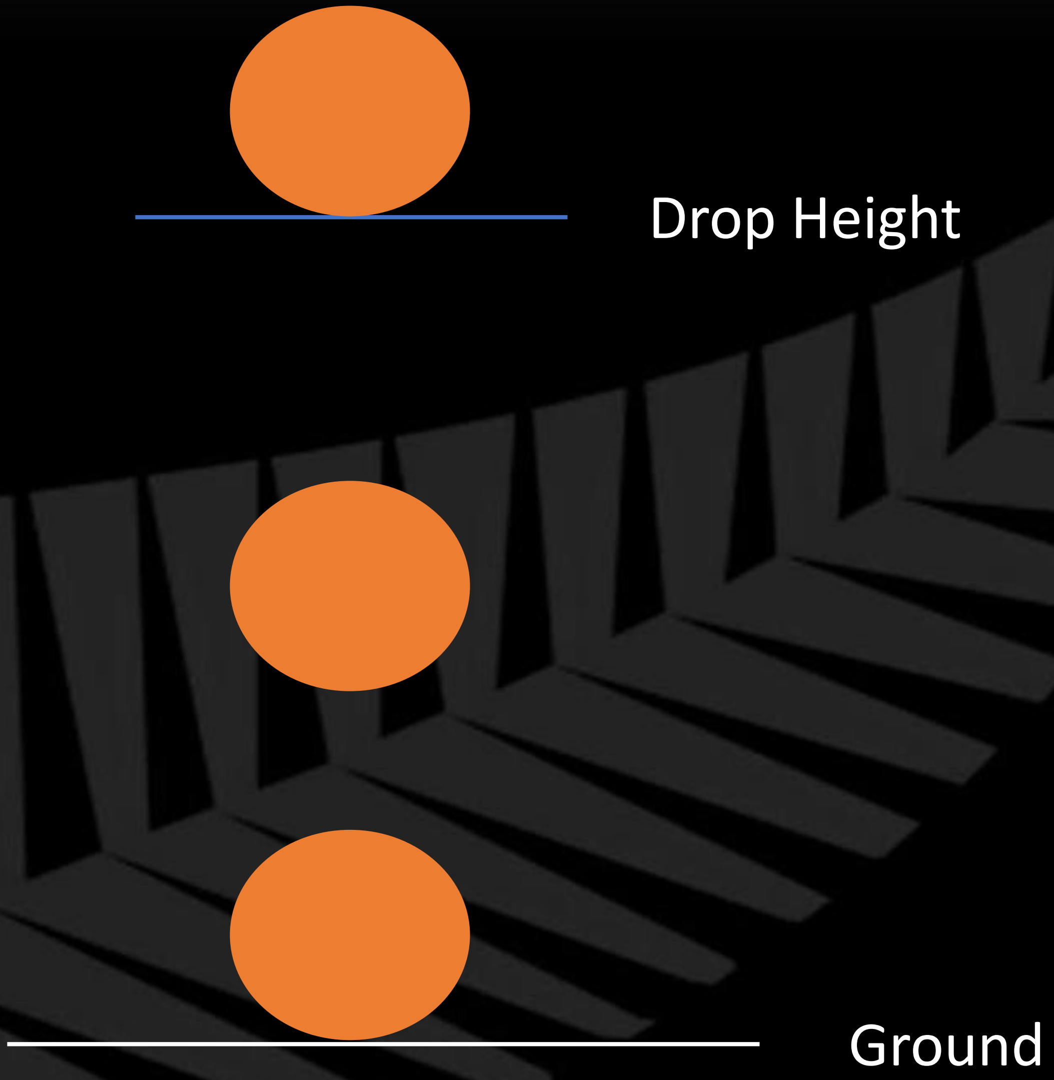
Method:	Accuracy:	Force:
Piezo chip	Analog	Yes
Sound	4.s.f +	No
High Speed Video	1.s.f	No
Motion Sensor	1.s.f	No

Theory

- Elastic and inelastic collision
- COR – Coefficient of Restitution

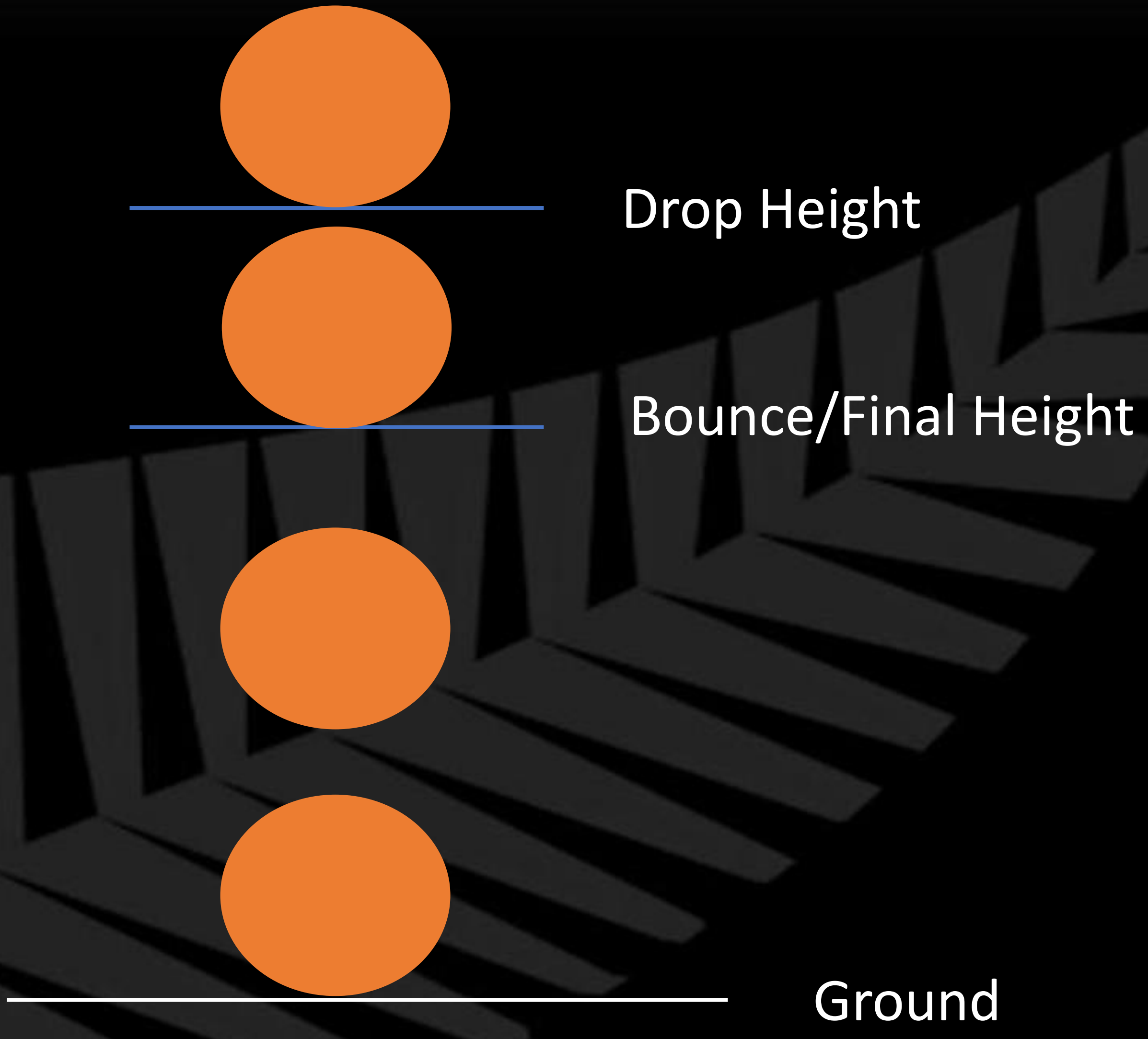
Theory

- Elastic collisions
  - No energy lost
  - Only occur on atomically level



Theory

- Inelastic collisions
  - Energy is lost
  - Most common type of collision



Theory

- COR - Coefficient of Restitution

$$Cr = \frac{V_f}{V_i}$$

$$Cr = \sqrt{\frac{2gh_f}{2gh_i}}$$

$$Cr = \sqrt{\frac{h_f}{h_i}}$$

Theory

- Energy transfers – conservation of energy

Gravitational Potential

↓

Kinetic

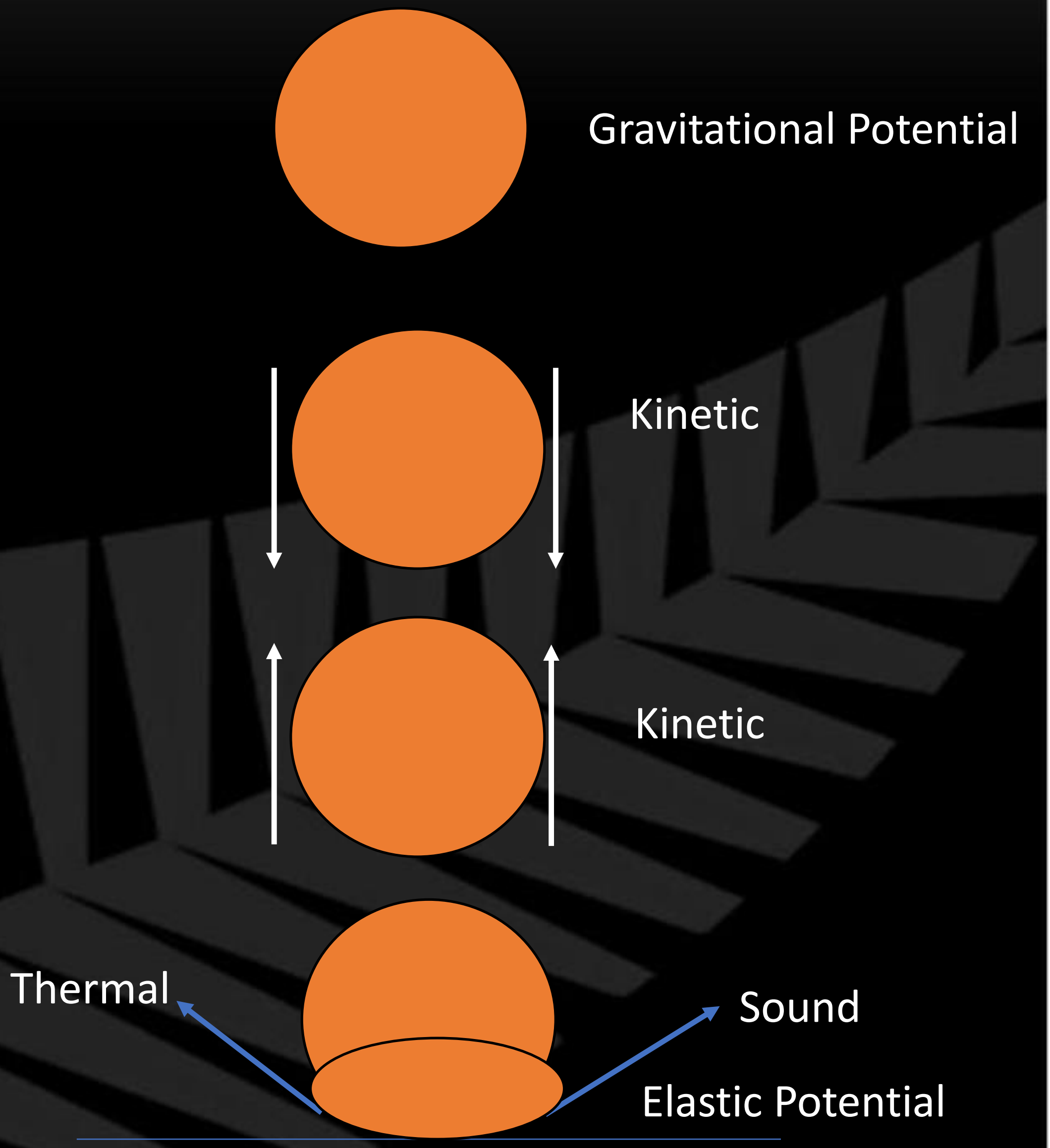
Sound ← Kinetic → Thermal

↓

Elastic Potential

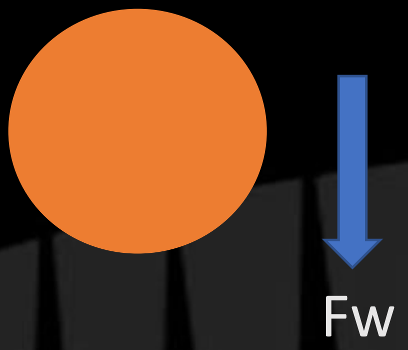
↓

Kinetic



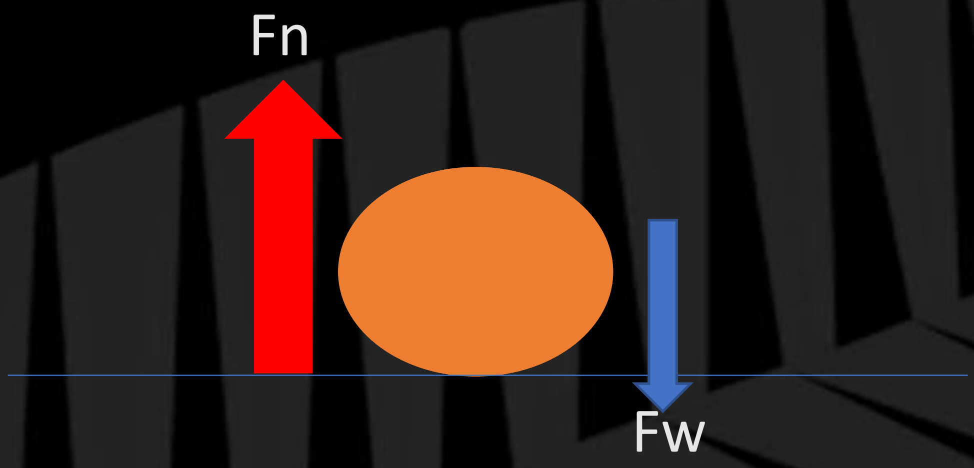
Theory

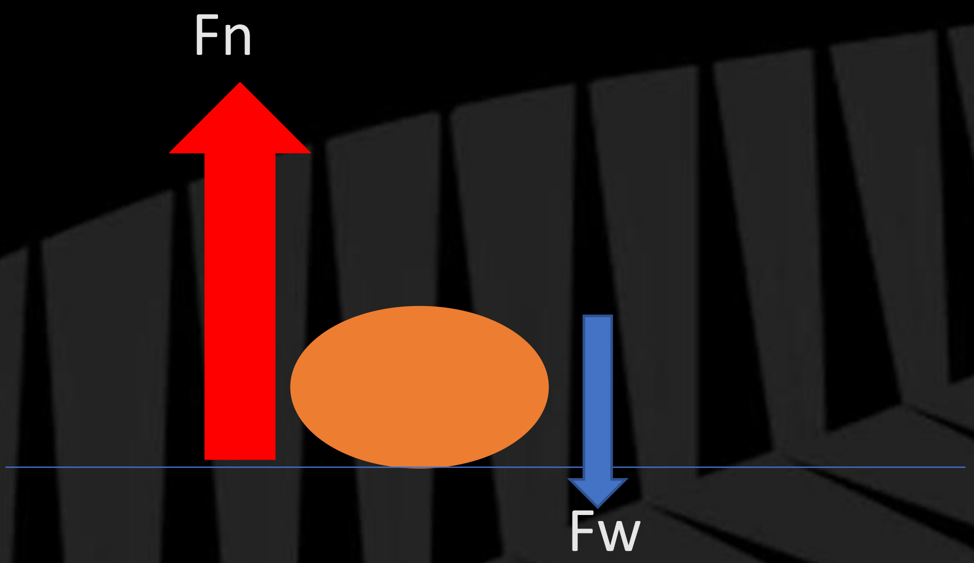
Fw= ball mass x 9.8

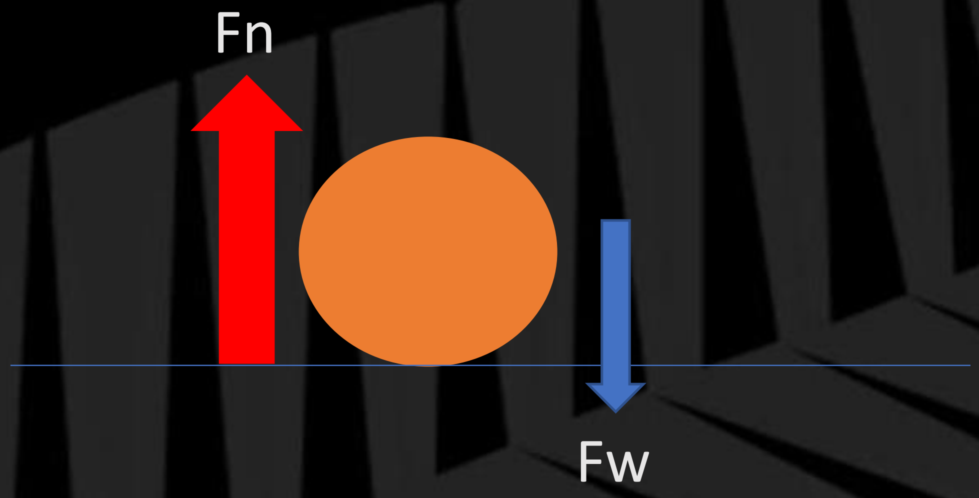



Fw


Fw


Fn
Fw


Fn
Fw


Fn
Fw


Fw

Finding the spring constant

- Hooke's Law – Hertz Adjustment

$$F = Force$$
$$k = Spring\ Constant$$
$$x = Extension\ or\ Compression$$

Spring:

$$F = -kx$$

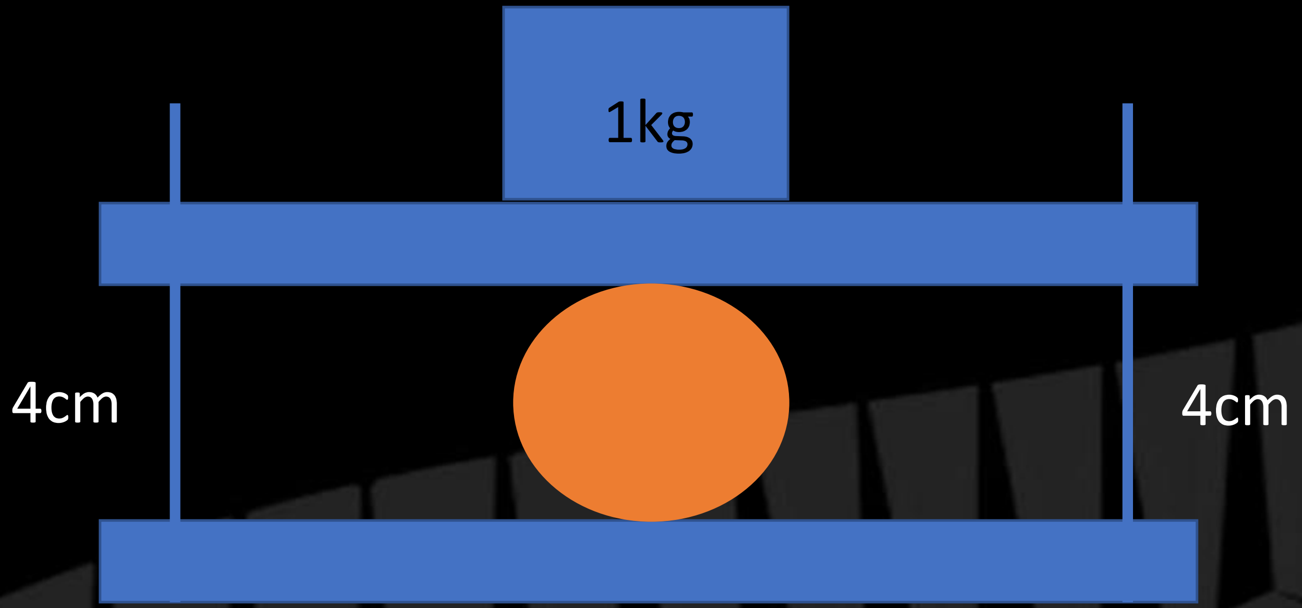
$$k = -\frac{F}{x}$$

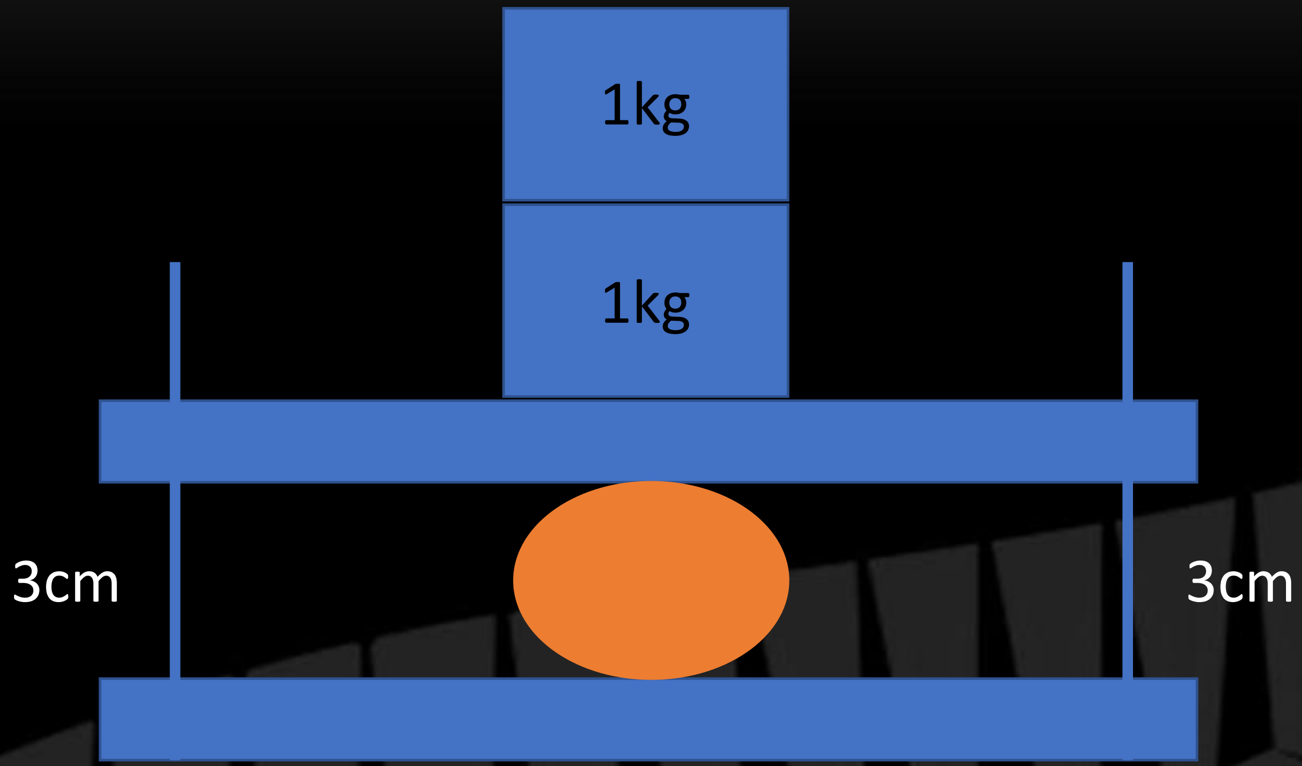
Ball:

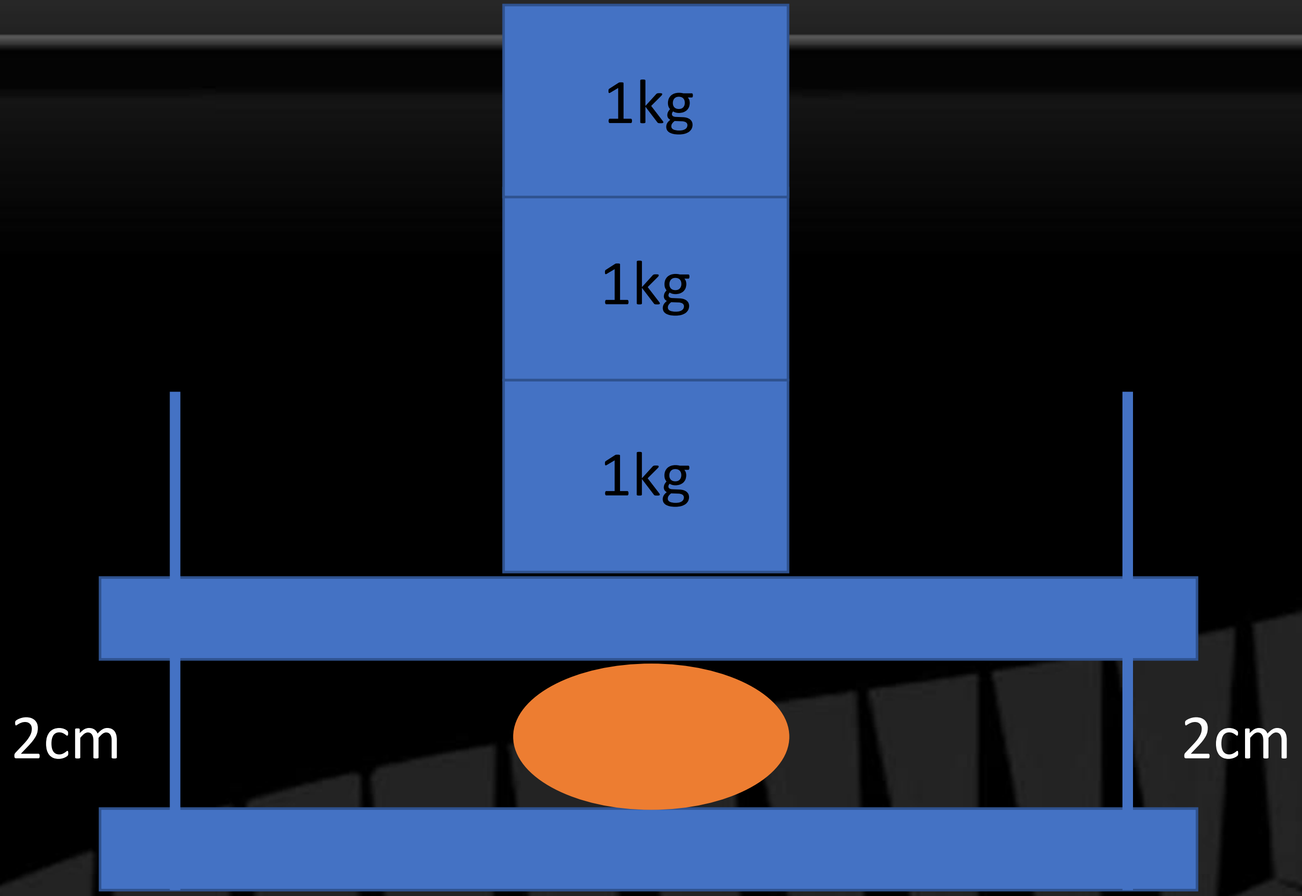
$$F = -kx^{\left(\frac{3}{2}\right)}$$

$$k = -\frac{F}{x^{\left(\frac{3}{2}\right)}}$$


5cm
5cm


1kg
4cm
4cm

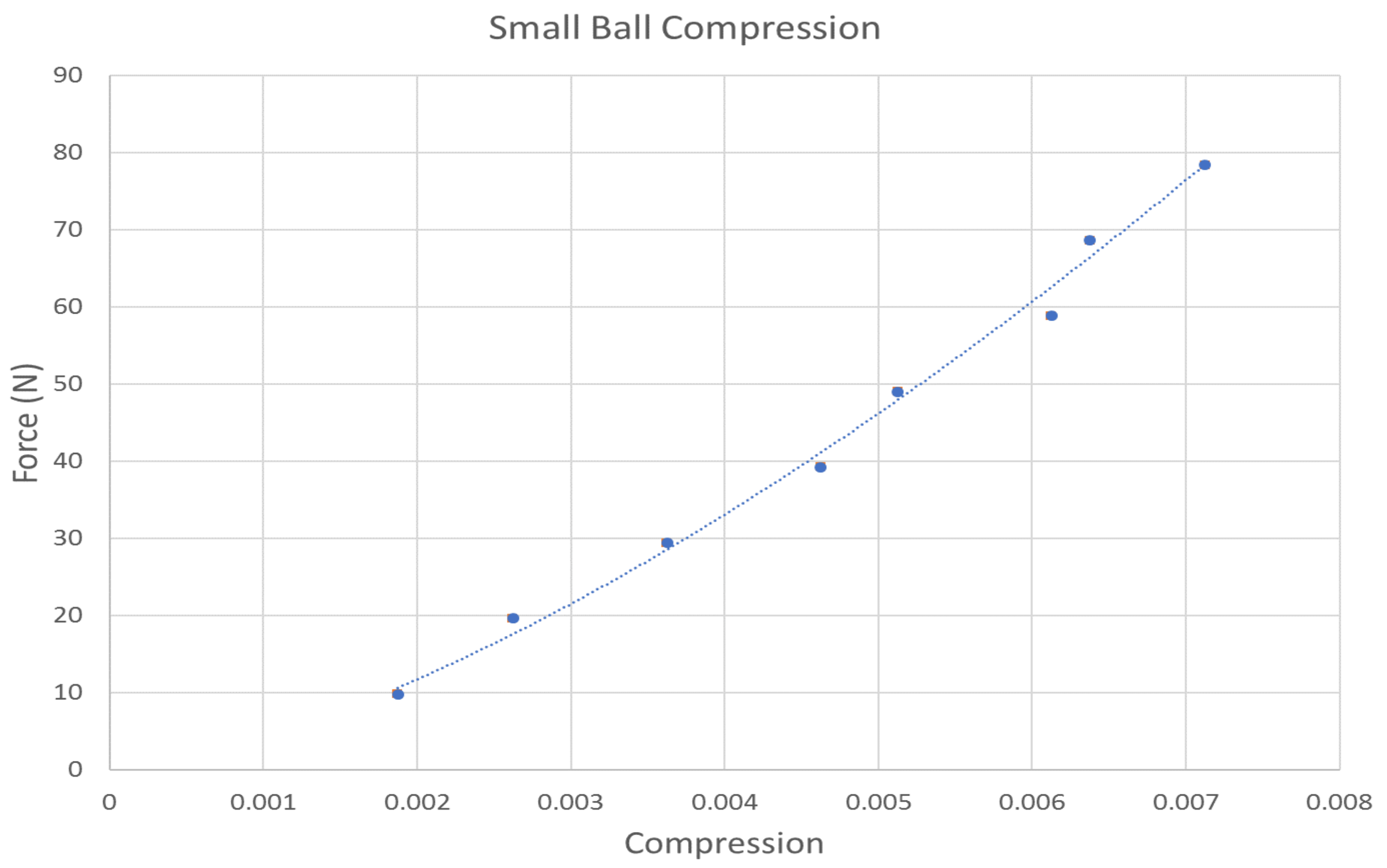

1kg
1kg
3cm
3cm


1kg
1kg
1kg
2cm
2cm

force (N)	A	B	C	D	average (cm)	difference (m	compression^3/2	force (N)
0	4.8	4.75	4.4	4.5	4.6125	0	0	0
9.8	4.2	4.5	4.7	4.3	4.425	0.001875	8.11899E-05	9.8
19.6	4	4.4	4.8	4.2	4.35	0.002625	0.000134491	19.6
29.4	4	4.2	4.5	4.3	4.25	0.003625	0.000218254	29.4
39.2	4.1	4.2	4.3	4	4.15	0.004625	0.000314534	39.2
49	4.1	4.1	4.1	4.1	4.1	0.005125	0.000366894	49
58.8	3.9	3.8	4.1	4.2	4	0.006125	0.000479357	58.8
68.6	3.5	3.9	4.5	4	3.975	0.006375	0.000509003	68.6
78.4	3.5	3.9	4.4	3.8	3.9	0.007125	0.000601419	78.4

Spring constant <u>without</u> Hertz adjustment.

$$k = -\frac{F}{x}$$



Spring constant with Hertz adjustment.

force (N)	A	B	C	D	average (cm)	difference (m	compression^3/2	force (N)
0	4.8	4.75	4.4	4.5	4.6125	0	0	0
9.8	4.2	4.5	4.7	4.3	4.425	0.001875	8.11899E-05	9.8
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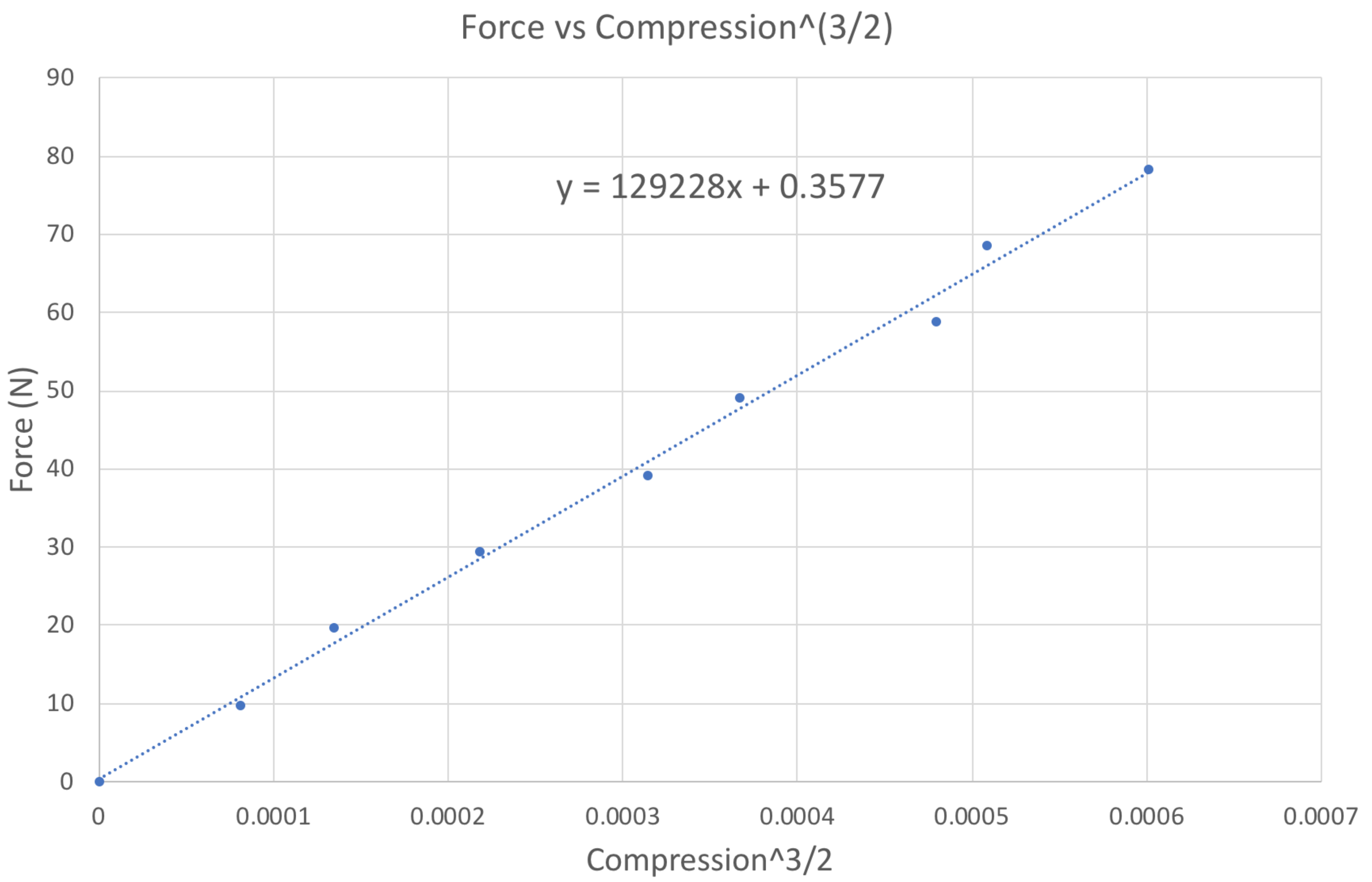
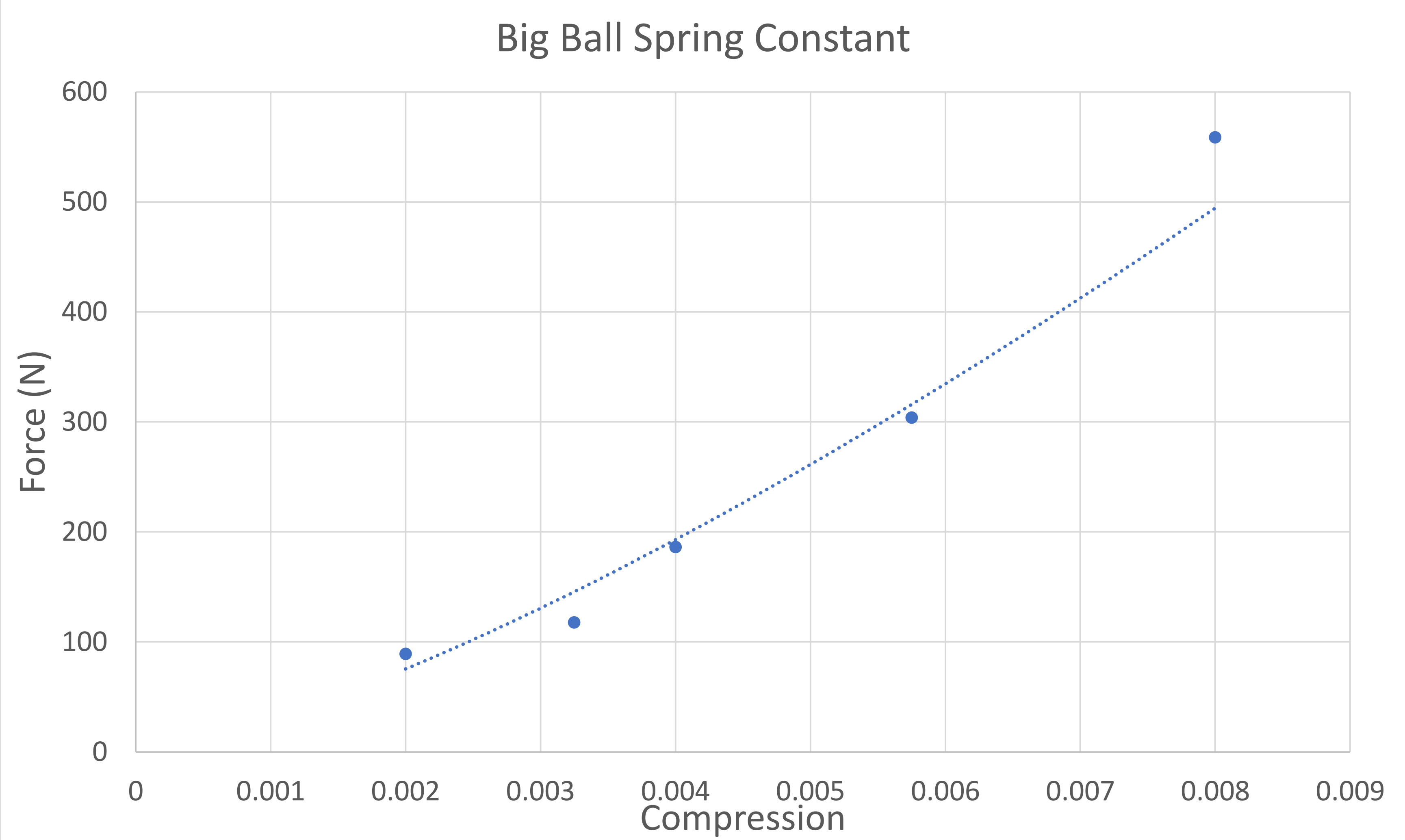


$$k = -\frac{F}{x^{\left(\frac{3}{2}\right)}}$$

$$k = 129000N/m^{\wedge}\left(\frac{3}{2}\right)$$

force (N)	A	B	C	D	average	difference	compression^3/2	force (N)
0	6.7	6.5	6.5	6.6	6.575	0	0	0
88.8958	6.5	6.3	6.3	6.4	6.375	0.002	8.94427E-05	88.8958
117.6	6.1	6.2	6.4	6.3	6.25	0.00325	0.000185279	117.6
186.2	6.2	6.4	6.2	5.9	6.175	0.004	0.000252982	186.2
303.8	6.4	6.4	5.6	5.6	6	0.00575	0.000436015	303.8
558.6	7.5	5.1	3.8	6.7	5.775	0.008	0.000715542	558.6

Spring constant <u>without</u> Hertz adjustment.



$$k = -\frac{F}{x}$$

force (N)	A	B	C	D	average	difference	compression^3/2	force (N)
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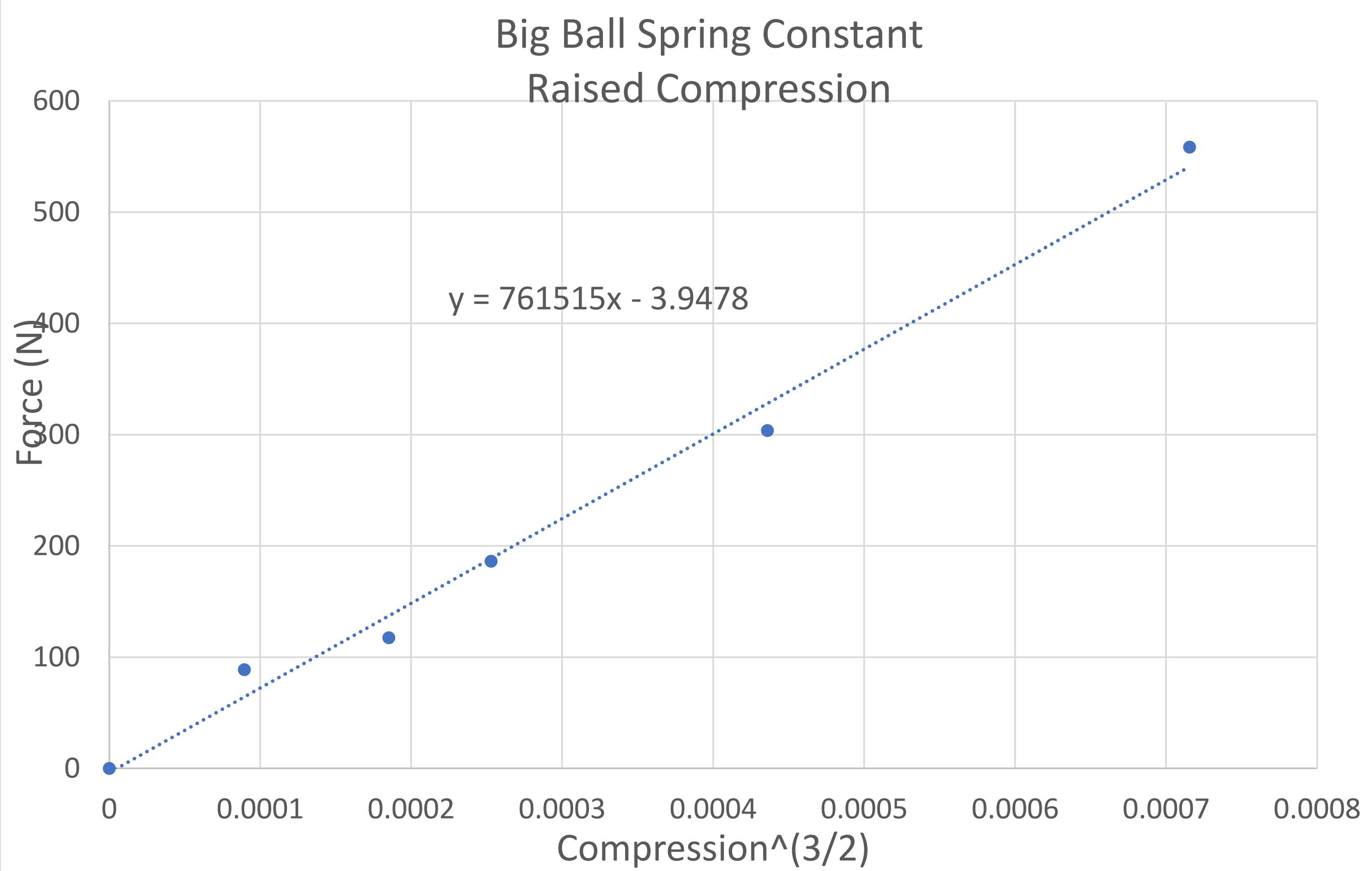
Spring constant with Hertz adjustment.



$$k = -\frac{F}{x^{\left(\frac{3}{2}\right)}}$$

$$k = 761000N/m^\wedge\left(\frac{3}{2}\right)$$

Theoretical Model

- Looks at displacement over time to predict collision time using:
  - Velocity
  - Spring Constant
  - Weight Force
  - Normal Force
  - Acceleration
  - Mass

time (s)	velocity	displacement	normal force	net force	acceleration		mass	0.075			
0	0.014	0	0	0.735	9.8		k	1520000			
0.00001	0.014098	1.4098E-07	-8.046E-05	0.734919540	9.7989272		initial velocity	0.014		height	0.00001
0.00002	0.014196	2.8294E-07	-0.00022876	0.734771237	9.79694983		radius	0.015			
0.00003	0.014294	4.25879E-07	-0.00042245	0.734577552	9.79436735						
0.00004	0.014392	5.69799E-07	-0.00065377	0.734346229	9.79128306						

Theoretical Model

- Looks at displacement over time to predict collision time using:
  - Velocity
  - Spring Constant
  - Weight Force
  - Normal Force
  - Acceleration
  - Mass

$$V_i = \sqrt{2gh}$$

$$V_f = V_i + at$$

time (s)	velocity	displacement	normal force	net force	acceleration		mass	0.075			
0	0.014	0	0	0.735	9.8		k	1520000			
0.00001	0.014098	1.4098E-07	-8.046E-05	0.734919540	9.7989272		initial velocity	0.014		height	0.00001
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0.00004	0.014392	5.69799E-07	-0.00065377	0.734346229	9.79128306						

Theoretical Model

- Looks at displacement over time to predict collision time using:
  - Velocity
  - Spring Constant
  - Weight Force
  - Normal Force
  - Acceleration
  - Mass

$$k = -\frac{f}{x^{\left(\frac{3}{2}\right)}}$$

time (s)	velocity	displacement	normal force	net force	acceleration		mass	0.075		
0	0.014	0	0	0.735	9.8		k	1520000		
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0.00004	0.014392	5.69799E-07	-0.00065377	0.734346229	9.79128306					

Theoretical Model

- Looks at displacement over time to predict collision time using:
  - Velocity
  - Spring Constant
  - Weight Force
  - Normal Force
  - Acceleration
  - Mass

$$F_W = mass \times 9.8$$

$$F_N = kx^{\left(\frac{3}{2}\right)}$$

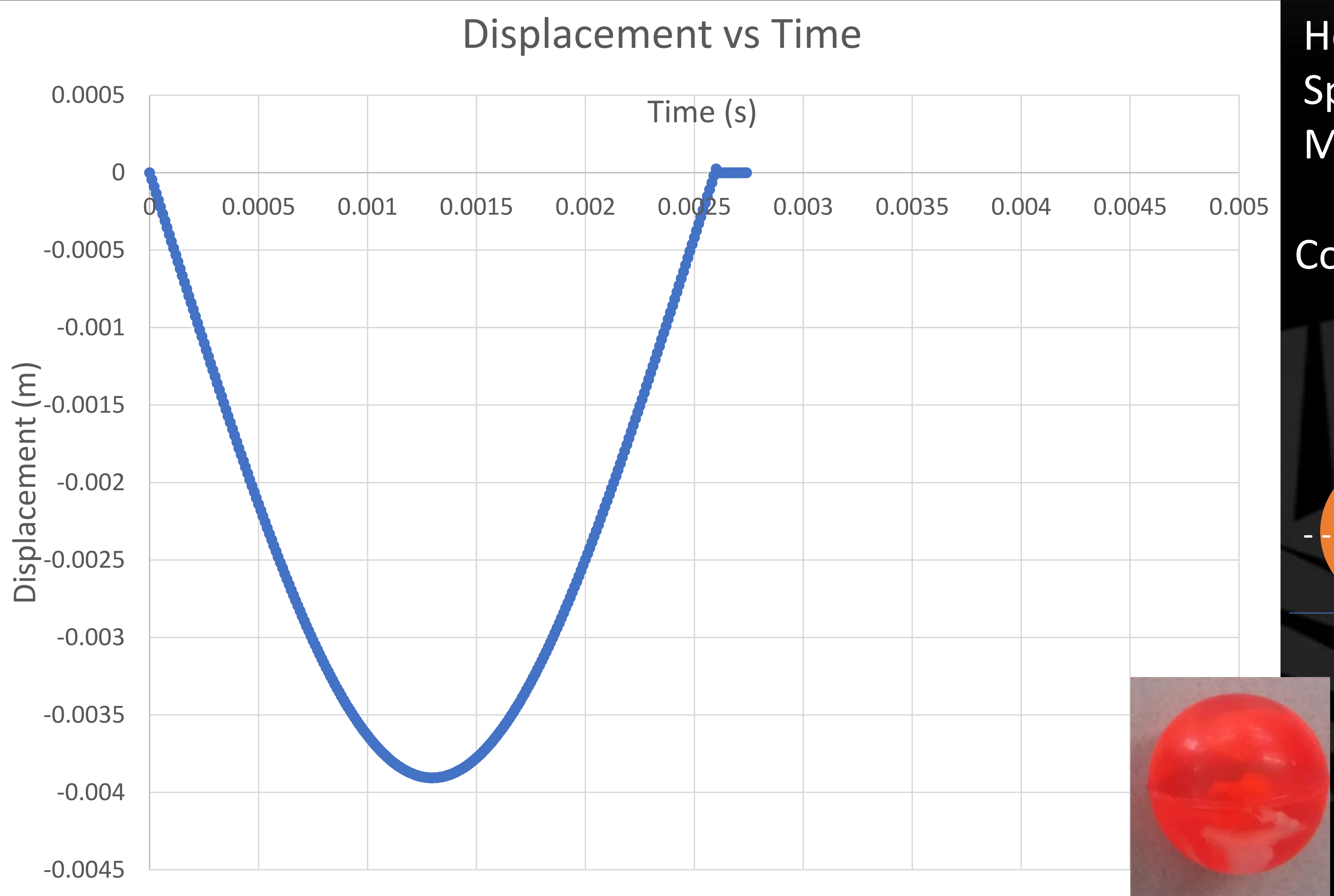
time (s)	velocity	displacement	normal force	net force	acceleration		mass	0.075			
0	0.014	0	0	0.735	9.8		k	1520000			
0.00001	0.014098	1.4098E-07	-8.046E-05	0.734919540	9.7989272		initial velocity	0.014		height	0.00001
0.00002	0.014196	2.8294E-07	-0.00022876	0.734771237	9.79694983		radius	0.015			
0.00003	0.014294	4.25879E-07	-0.00042245	0.734577552	9.79436735						
0.00004	0.014392	5.69799E-07	-0.00065377	0.734346229	9.79128306						

Theoretical Model

- Looks at displacement over time to predict collision time using:
  - Velocity
  - Spring Constant
  - Weight Force
  - Normal Force
  - Acceleration
  - Mass

$$a = \frac{F_{net}}{m}$$

time (s)	velocity	displacement	normal force	net force	acceleration		mass	0.075			
0	0.014	0	0	0.735	9.8		k	1520000			
0.00001	0.014098	1.4098E-07	-8.046E-05	0.734919540	9.7989272		initial velocity	0.014		height	0.00001
0.00002	0.014196	2.8294E-07	-0.00022876	0.734771237	9.79694983		radius	0.015			
0.00003	0.014294	4.25879E-07	-0.00042245	0.734577552	9.79436735						
0.00004	0.014392	5.69799E-07	-0.00065377	0.734346229	9.79128306						

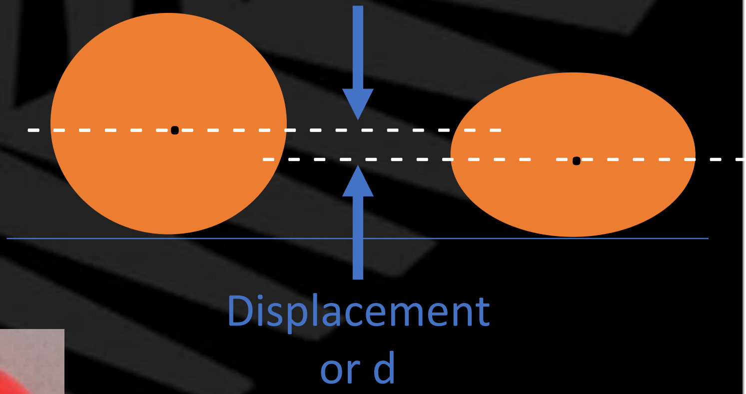


Height: 1m

Spring Constant: 258000

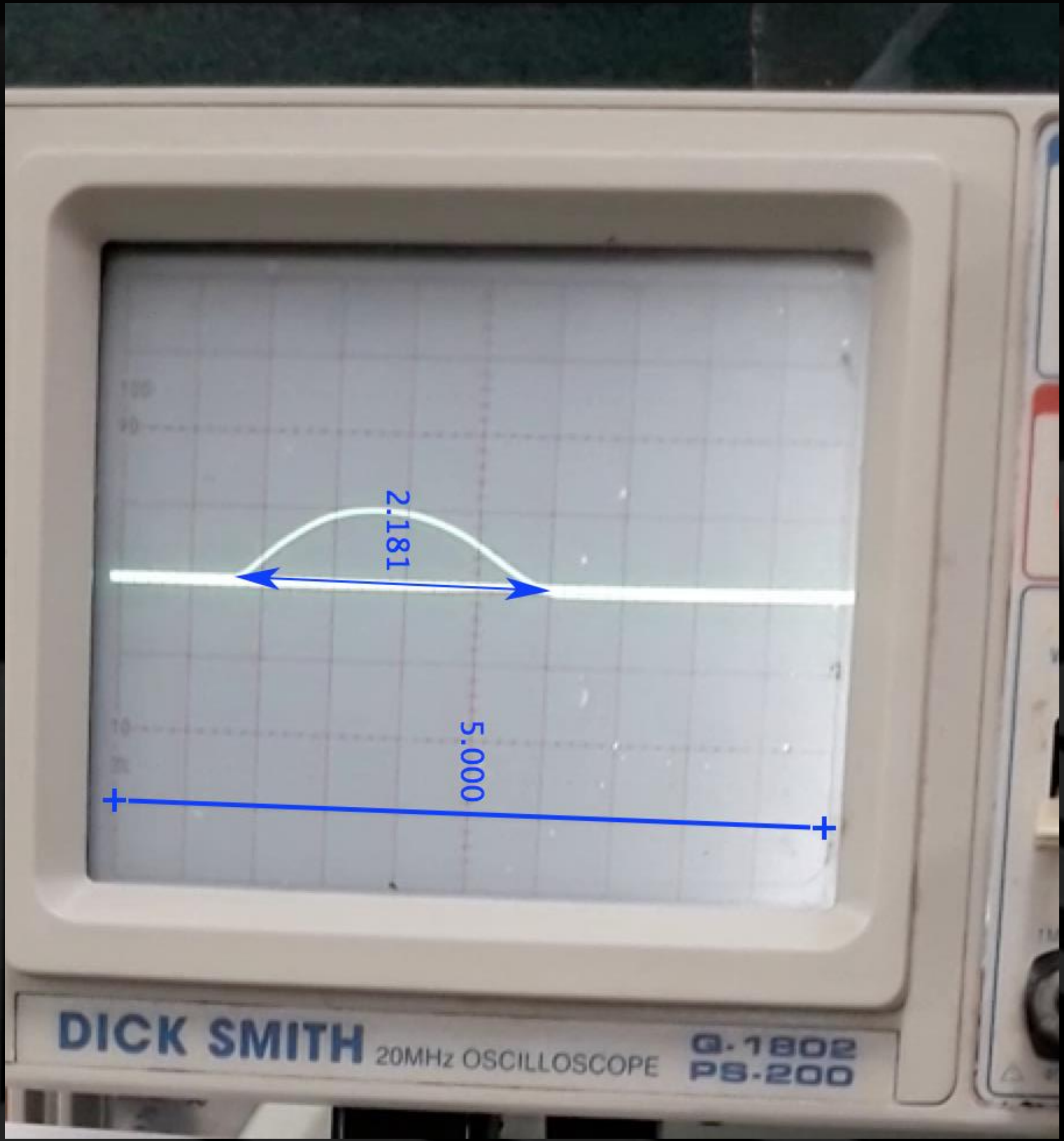
Mass: 0.01kg

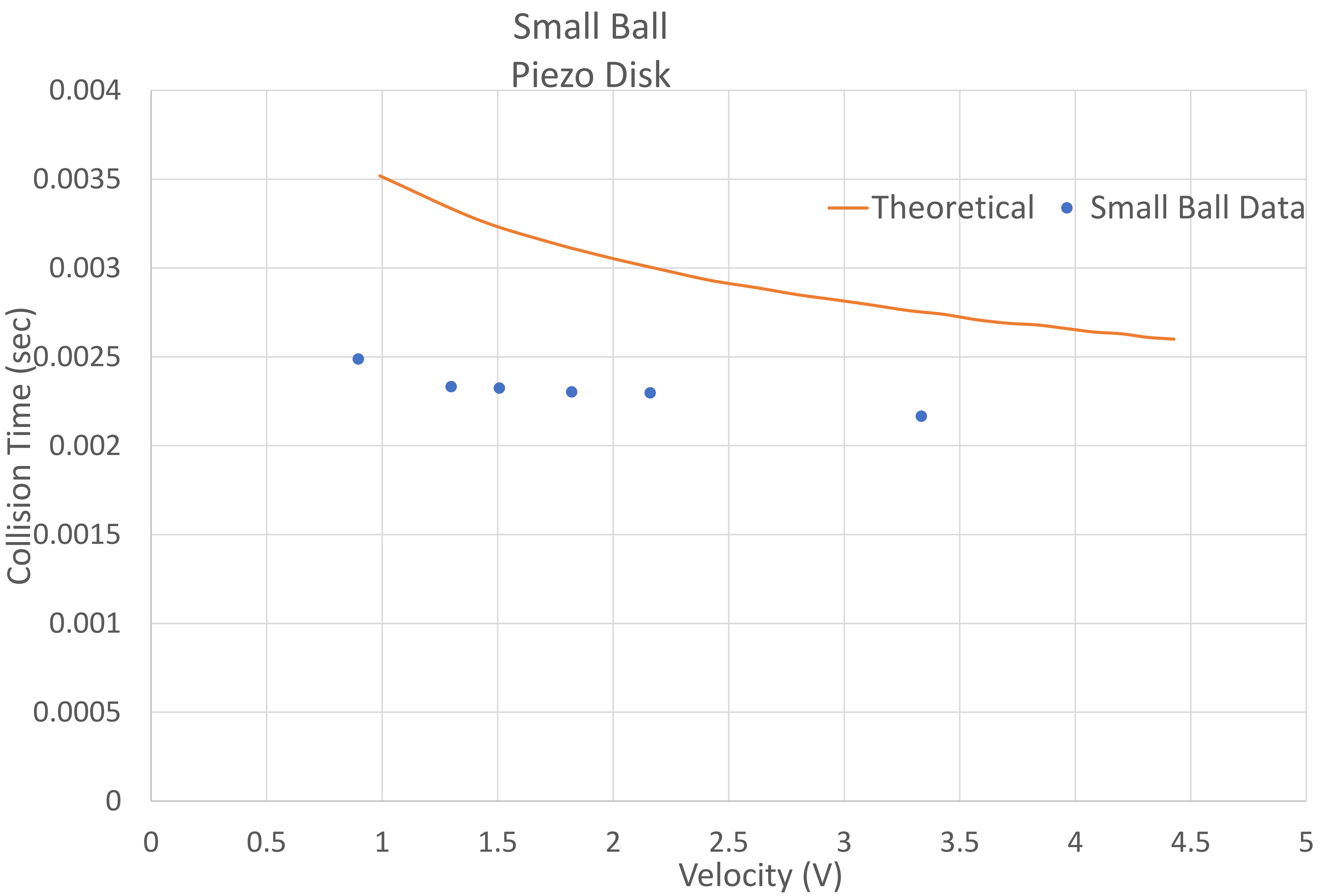
Collision time=0.00259 sec



Piezo Chip

- Voltage over time
- Oscilloscope





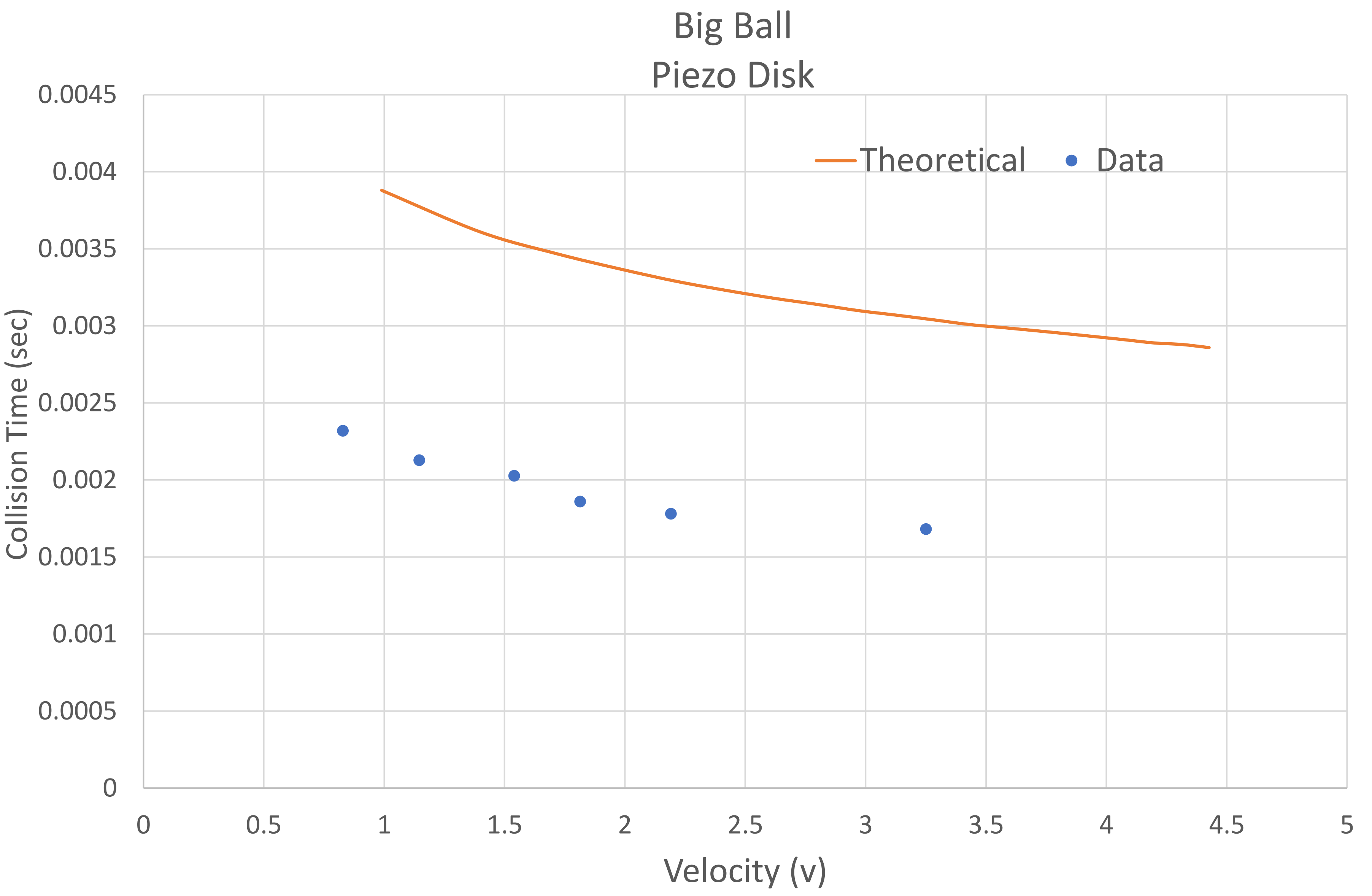
Ball Mass = 0.010kg

$$k = 129000 N/m\hat{}\left(\frac{3}{2}\right)$$

$$\underline{Velocity\ (V) = \sqrt{2gh}}$$

$$g\ (gravity) = 9.8$$

$$h = drop\ height$$



Ball Mass = 0.075kg

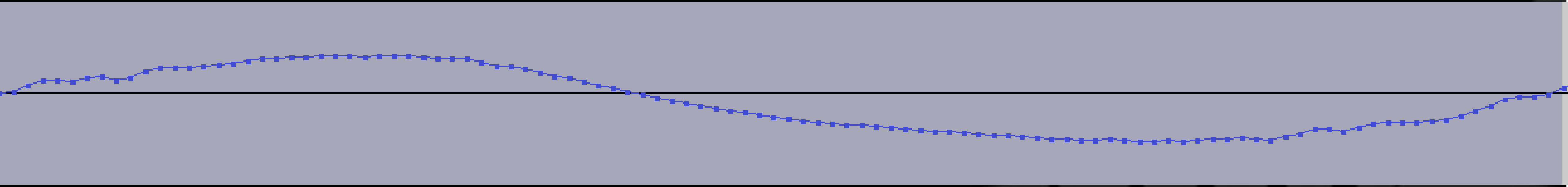
$$k = 761000N/m^{\wedge}(\frac{3}{2})$$

$$Velocity\ (V) = \sqrt{2gh}$$

$$g\ (gravity) = 9.8$$

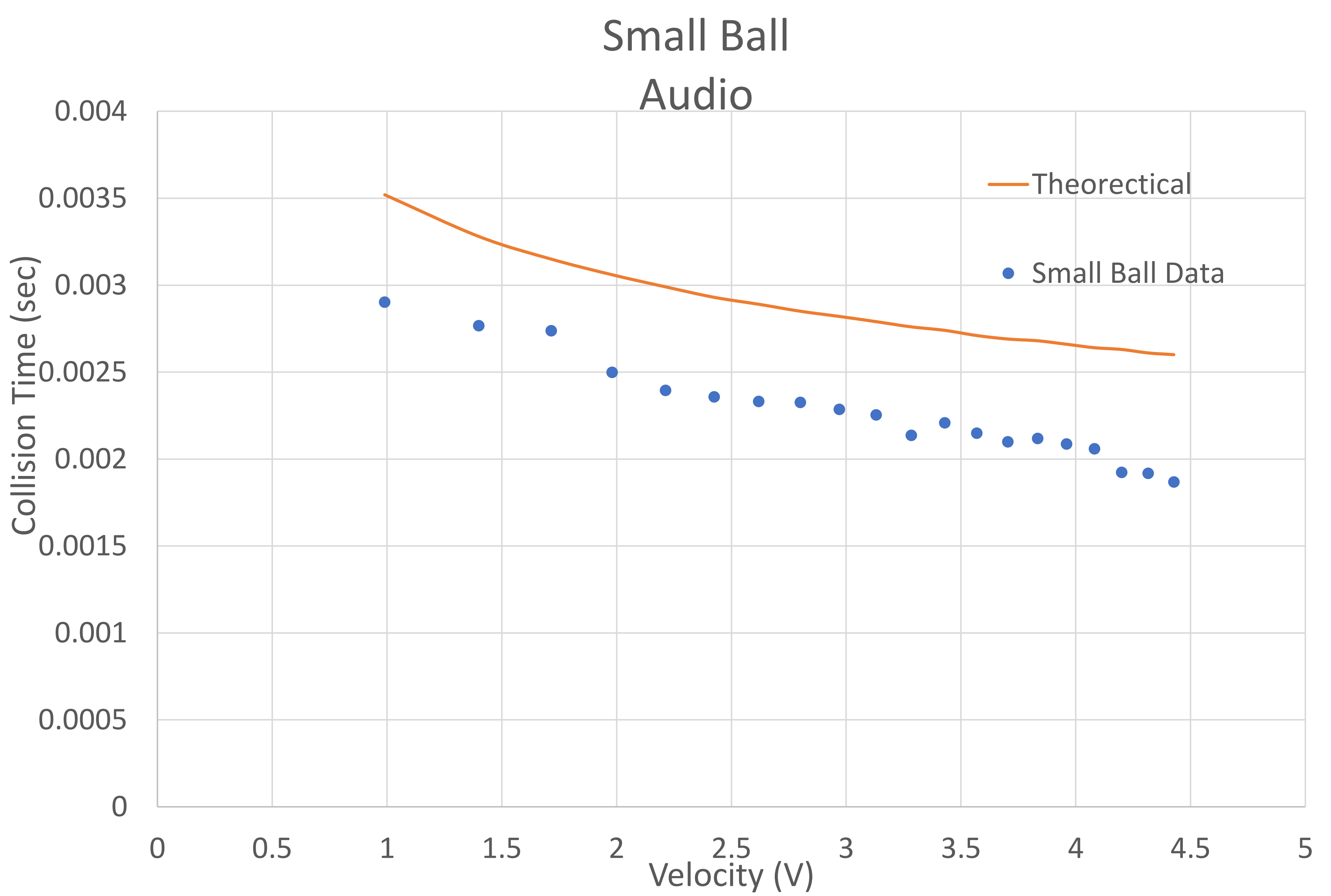
$$h = drop\ height$$

Sound:



Sample rate (HZ) = 44100

Collision Time = $\frac{101}{44100} = 0.00229ms$



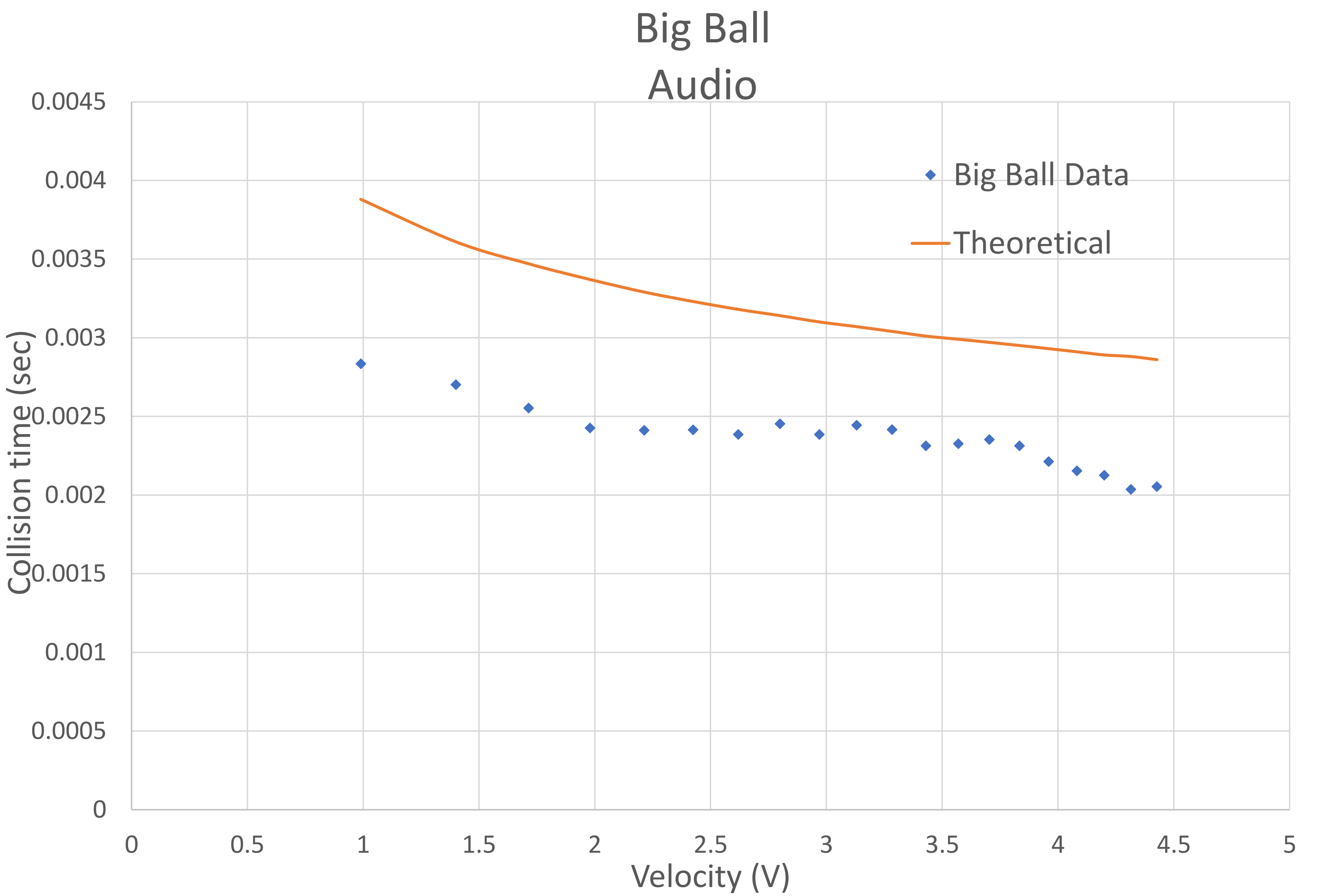
Ball Mass = 0.010kg

$k = 129000N/m\text{^}(\frac{3}{2})$

$\underline{Velocity\ (V) = \sqrt{2gh}}$

$g\ (gravity)\ =\ 9.8$

$h\ =\ drop\ height$



Ball Mass = 0.075kg

$$k = 761000N/m\hat{}(\frac{3}{2})$$

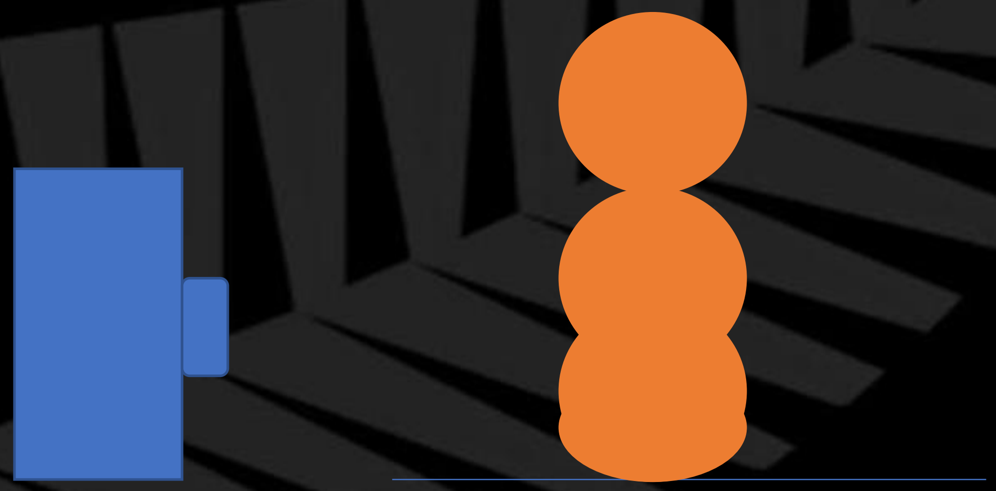
$$Velocity\ (V) = \sqrt{2gh}$$

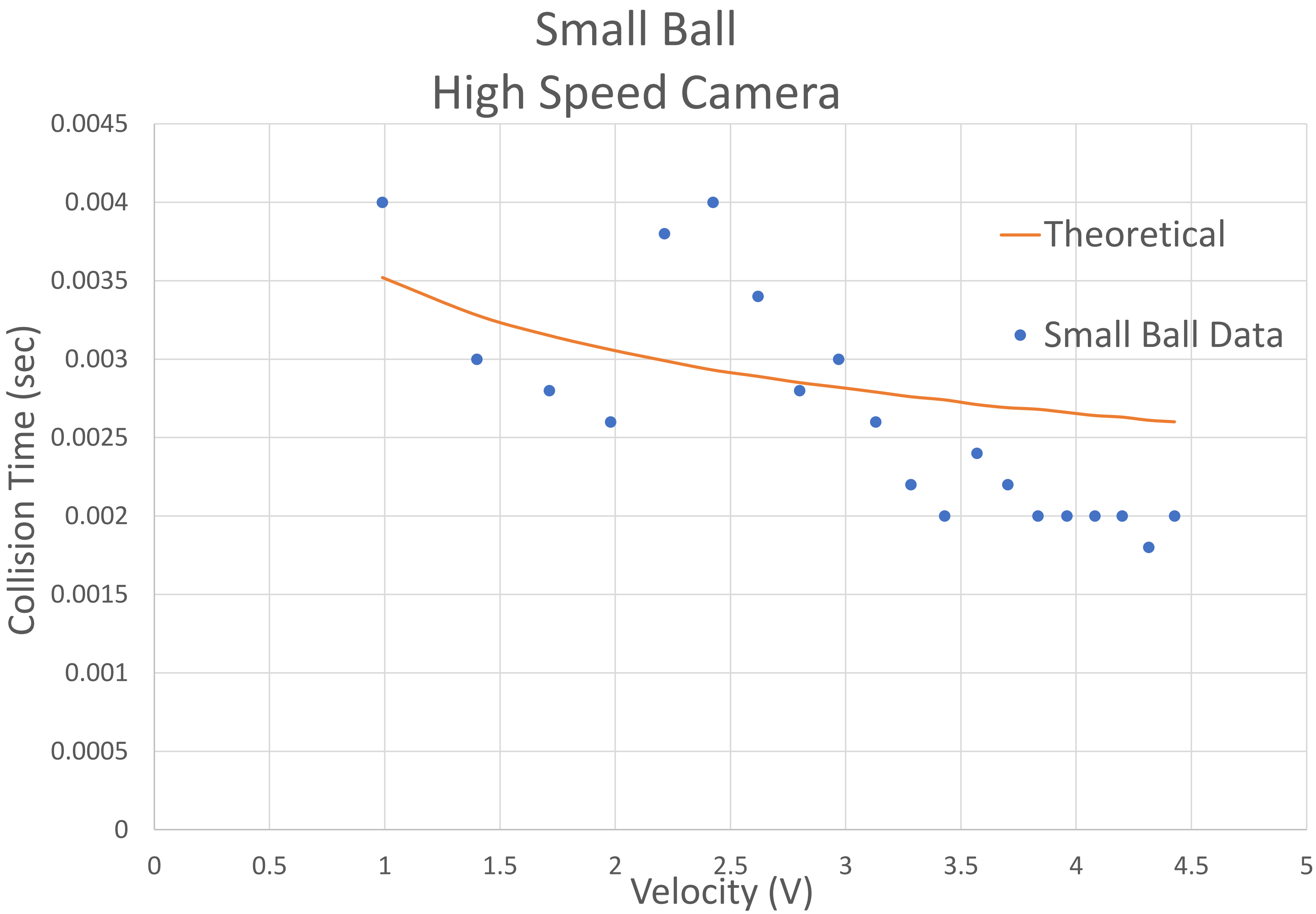
$$g\ (gravity) = 9.8$$

$$h = drop\ height$$

High Speed Video

- Frame Rate – 1000fps
- Set up





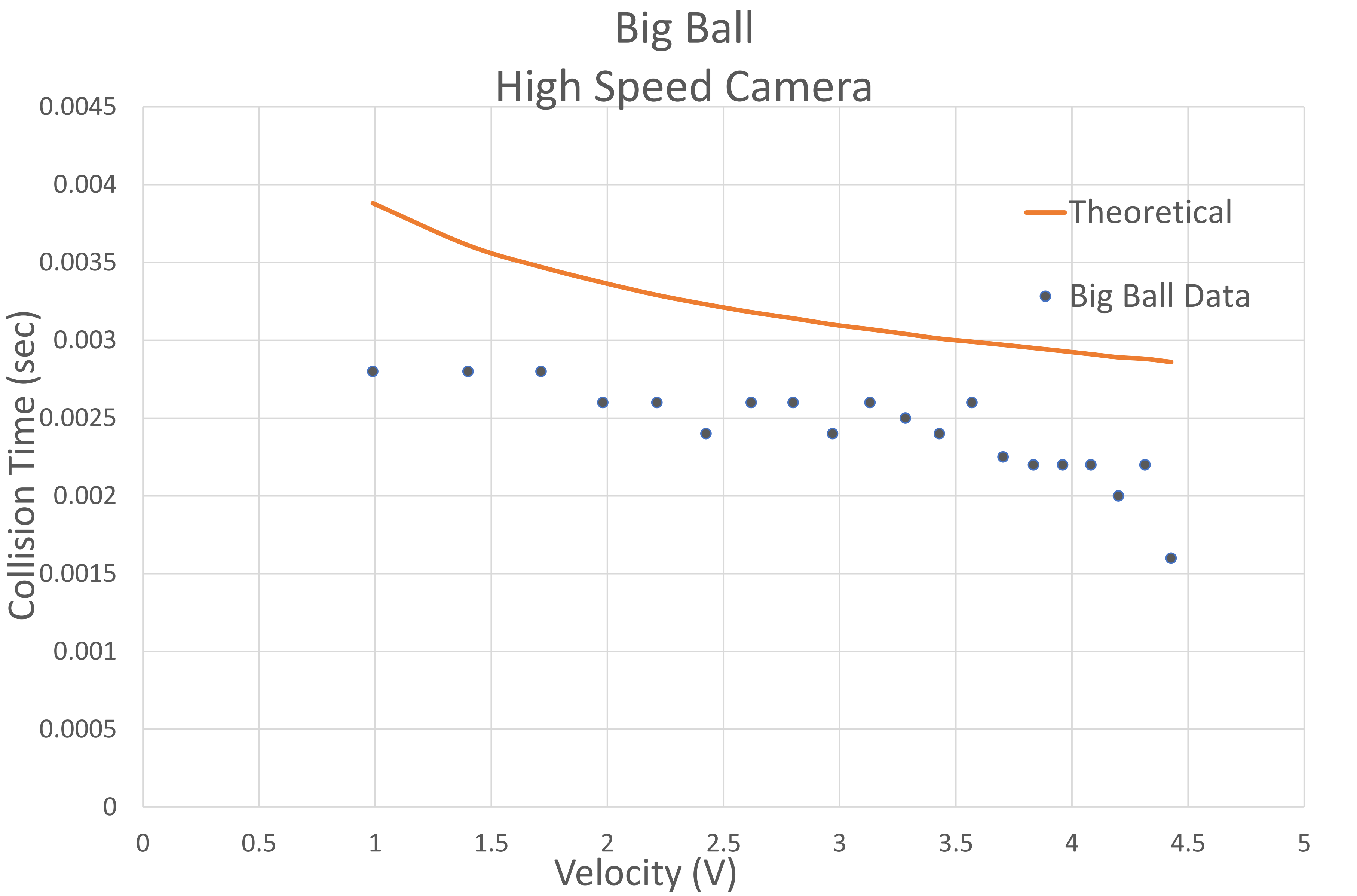
Ball Mass = 0.010kg

$$k = 129000N/m\hat{}(\frac{3}{2})$$

$$\underline{Velocity\ (V) = \sqrt{2gh}}$$

$$g\ (gravity) = 9.8$$

$$h = drop\ height$$



Ball Mass = 0.075kg

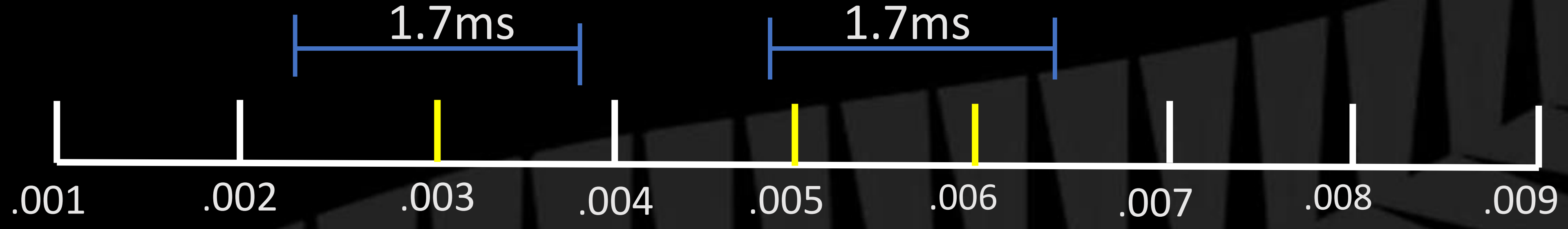
$$k = 761000N/m^{\wedge}\left(\frac{3}{2}\right)$$

$$Velocity\ (V) = \sqrt{2gh}$$

$$g\ (gravity) = 9.8$$

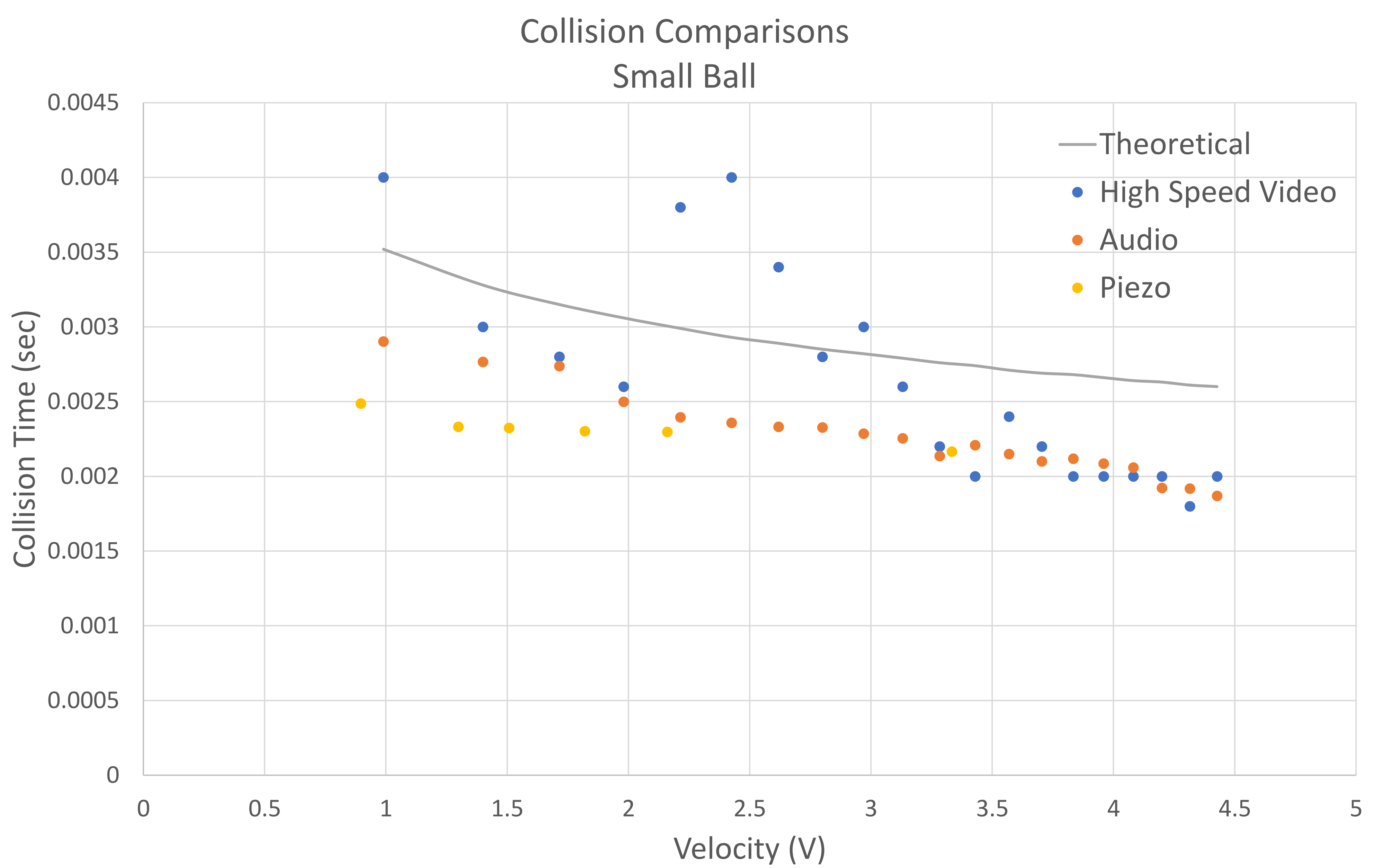
$$h = drop\ height$$

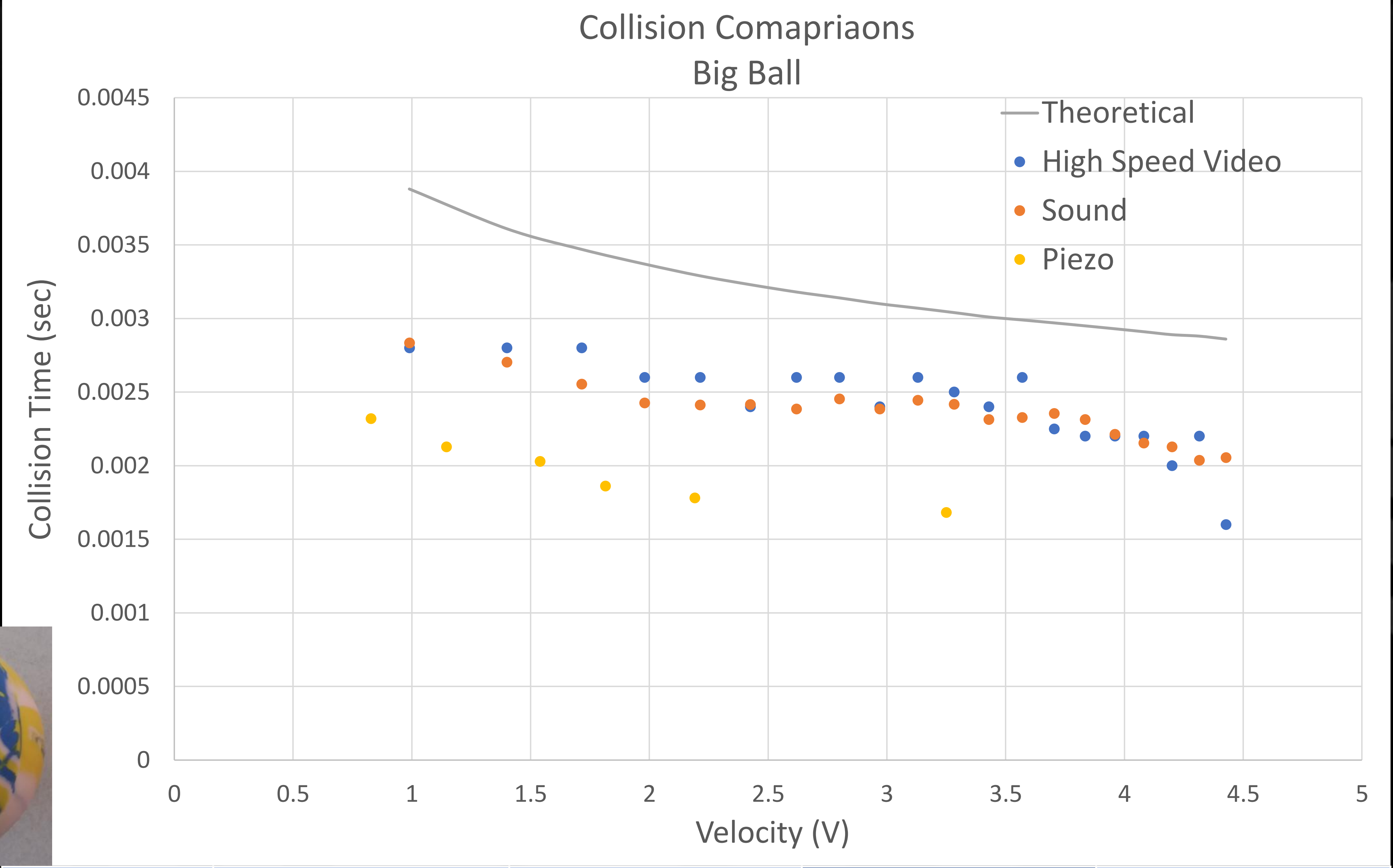
Option 1: **Option 2:**



Option 1= 0.001sec or 1ms

Option 2 = 0.002sec or 2ms

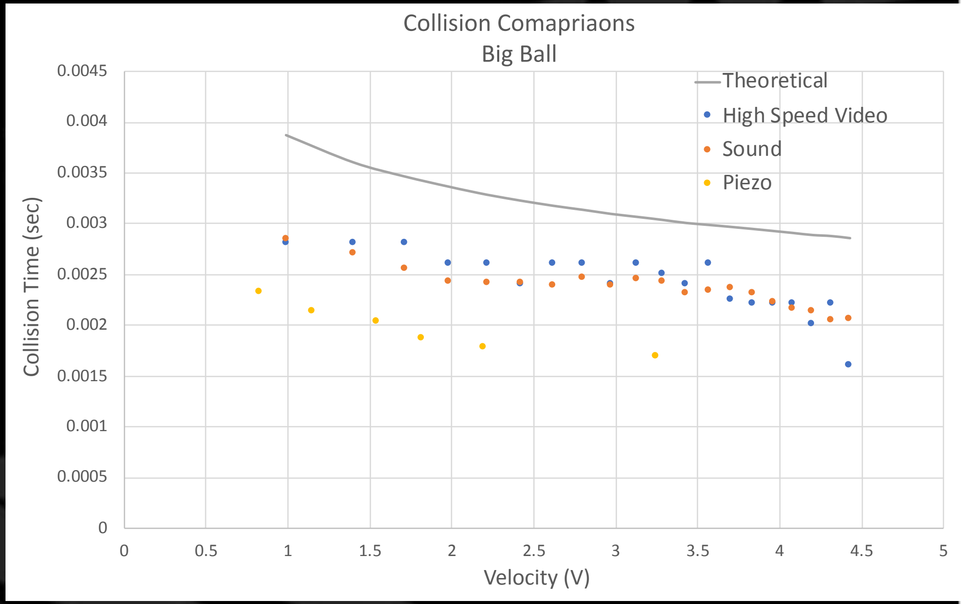

Collision Comparisons
Small Ball
Collision Time (sec)
Velocity (V)
0.0045
0.004
0.0035
0.003
0.0025
0.002
0.0015
0.001
0.0005
0
0
0.5
1
1.5
2
2.5
3
3.5
4
4.5
5
Theoretical
High Speed Video
Audio
Piezo


Collision Comapriaons
Big Ball
Collision Time (sec)
Velocity (V)
0.0045
0.004
0.0035
0.003
0.0025
0.002
0.0015
0.001
0.0005
0
0
0.5
1
1.5
2
2.5
3
3.5
4
4.5
5
Theoretical
High Speed Video
Sound
Piezo

Conclusion:

"A highly elastic Super Ball collides with a rigid surface. How can one determine the collision time? Propose various techniques and compare the experimental results."

- High speed video
- Piezo disk – Voltage over time
- Sound
- Motion sensor



Acknowledgments:

- Murray Chisholm
- Family
- Ryan 'Hell Fire' Bright & other minions
- The NZ IYNT Team

References:

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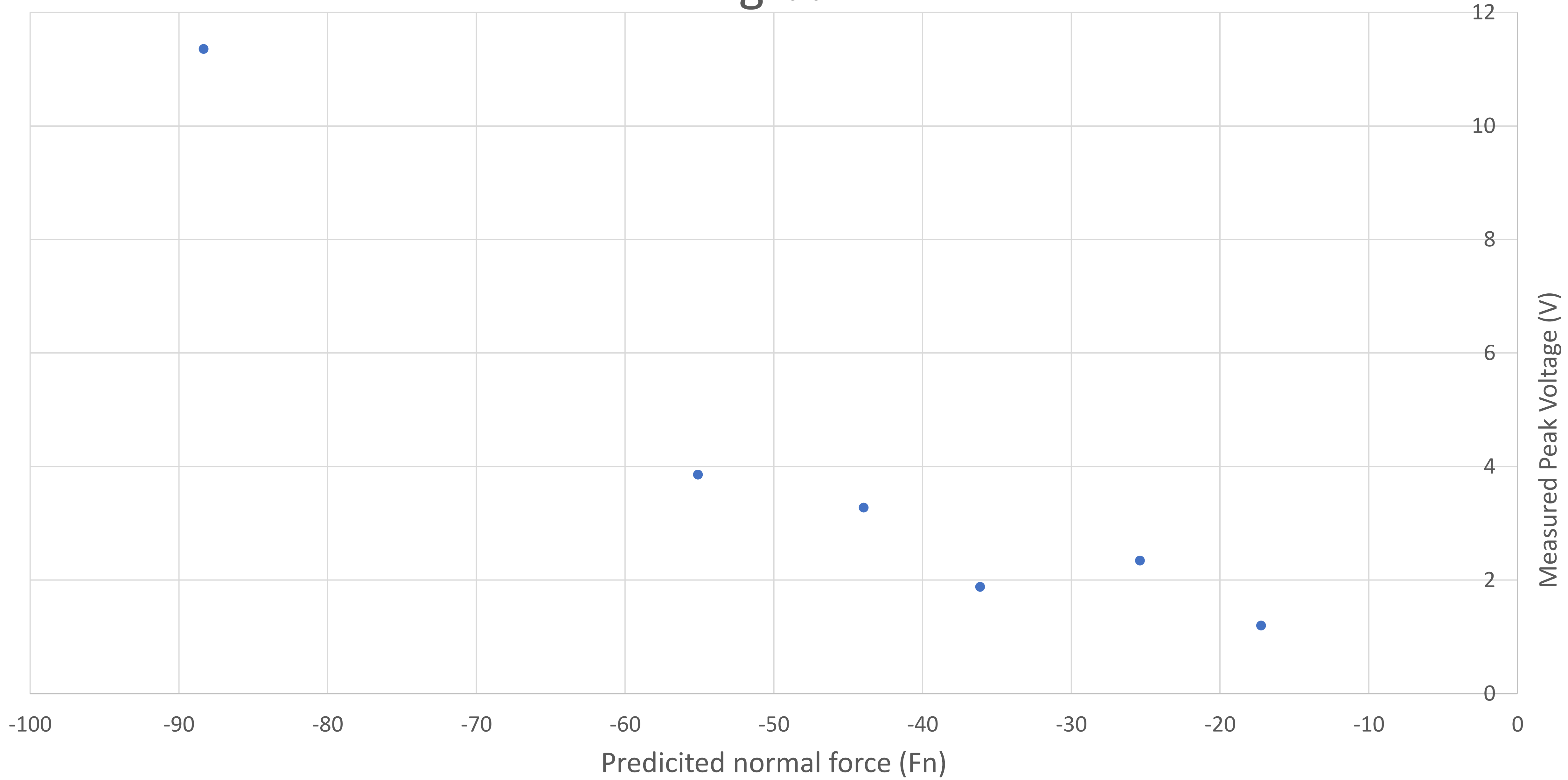
http://www.physicsclassroom.com/class/newtlaws/Lesson-1/Inertia-and-Mass

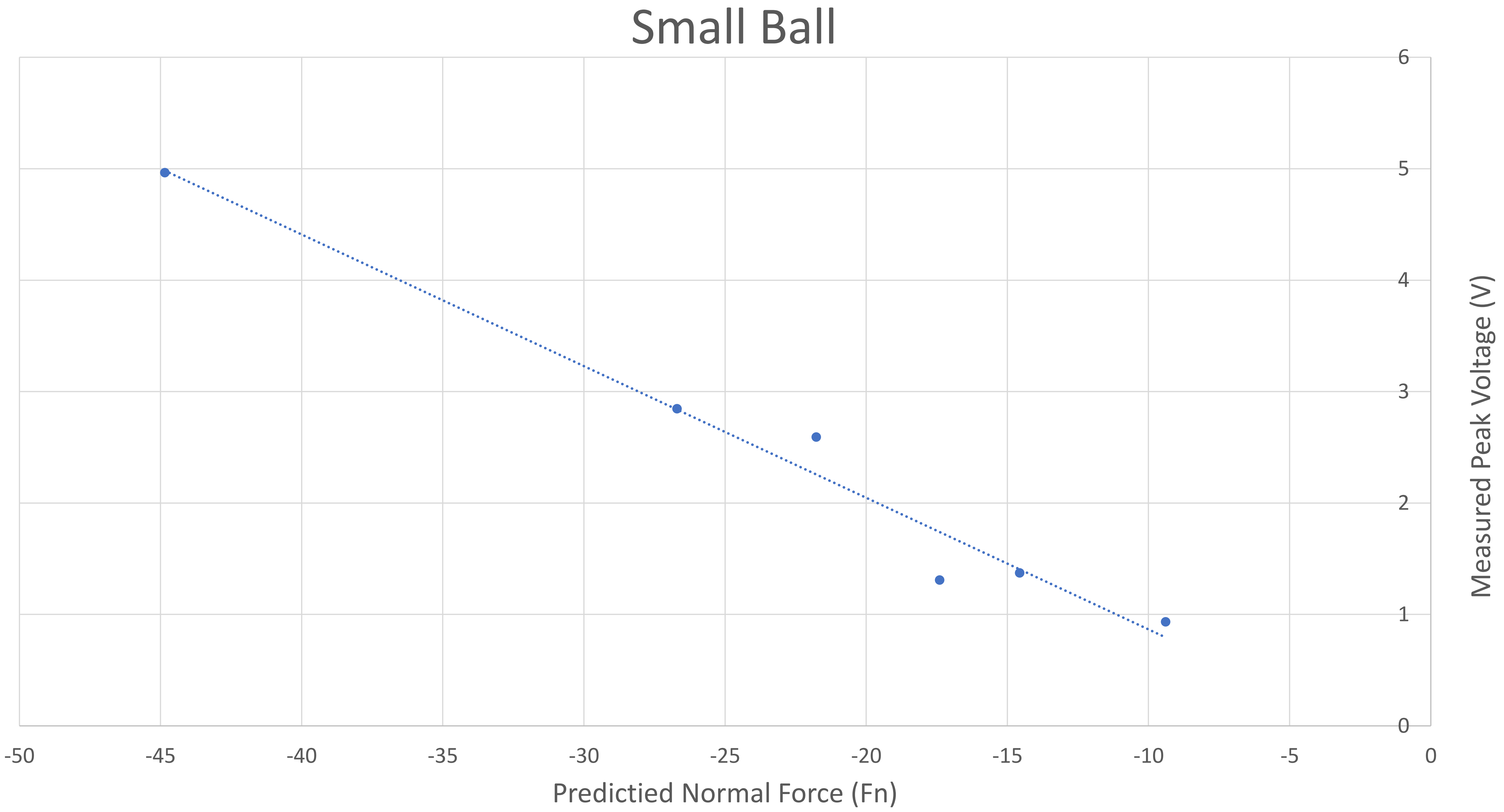
http://hyperphysics.phy-astr.gsu.edu/hbase/mi.html

5. Collision

Ella Blakely
New Zealand

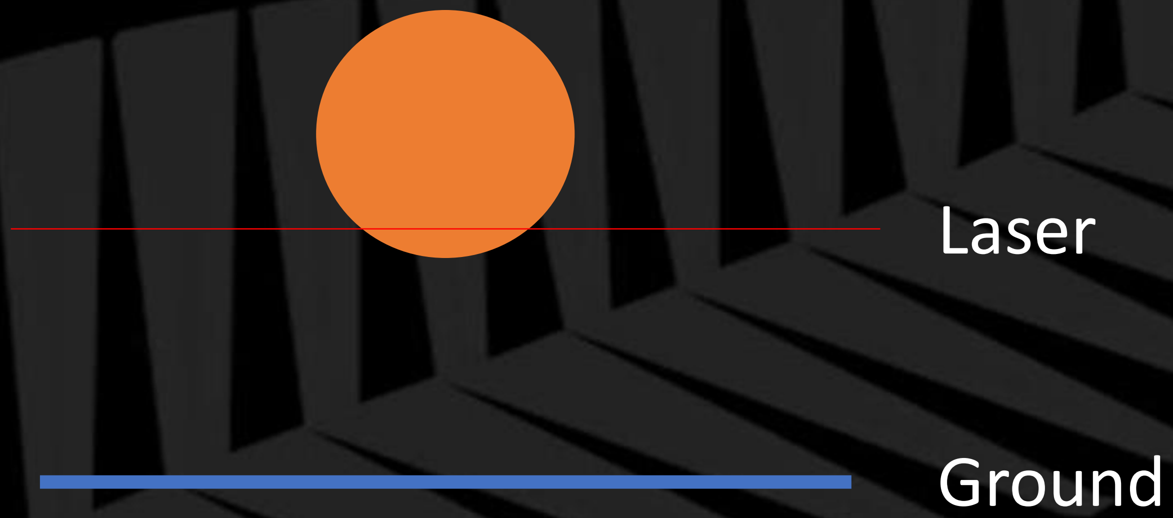
Big ball


12
10
8
6
4
2
0
-100
-90
-80
-70
-60
-50
-40
-30
-20
-10
0
Measured Peak Voltage (V)
Predicited normal force (Fn)


Small Ball
Measured Peak Voltage (V)
Predictied Normal Force (Fn)
0
1
2
3
4
5
6
-50
-45
-40
-35
-30
-25
-20
-15
-10
-5
0

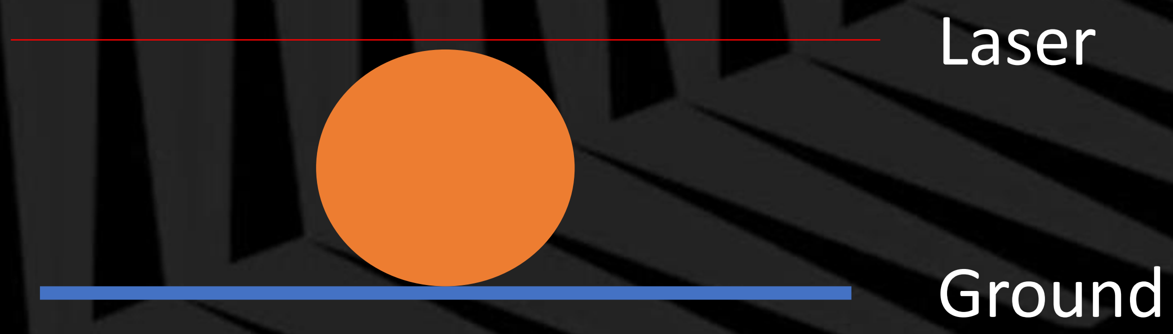
Lasers:

Lasers:



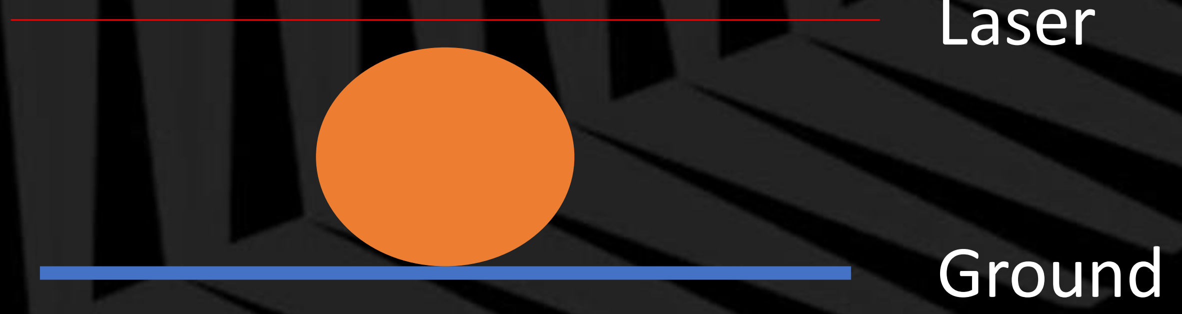
Lasers:

Starts Timing:



Lasers:

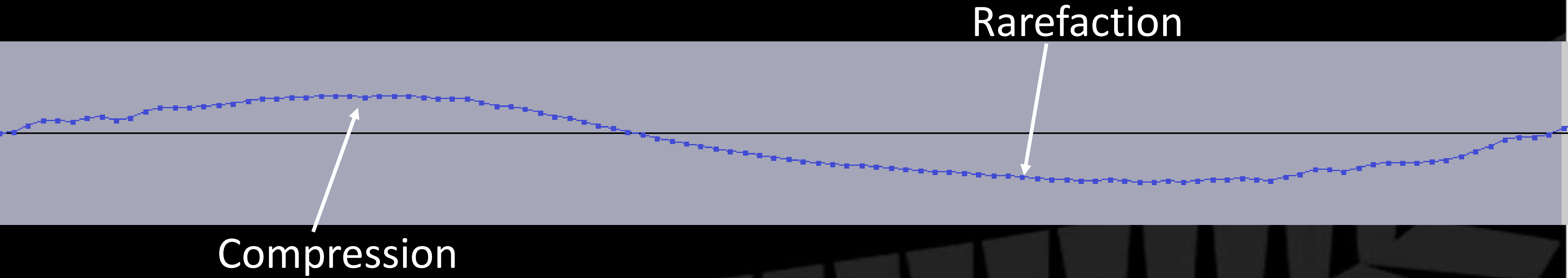
Lasers:



Lasers:

Stops Timing:

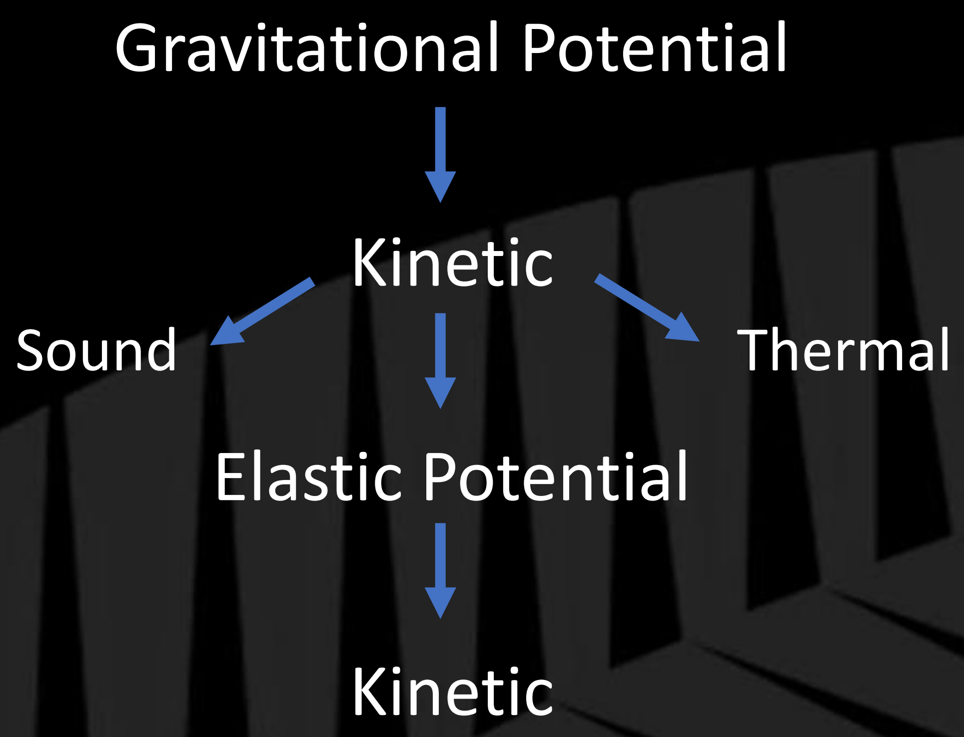
Why sound works?

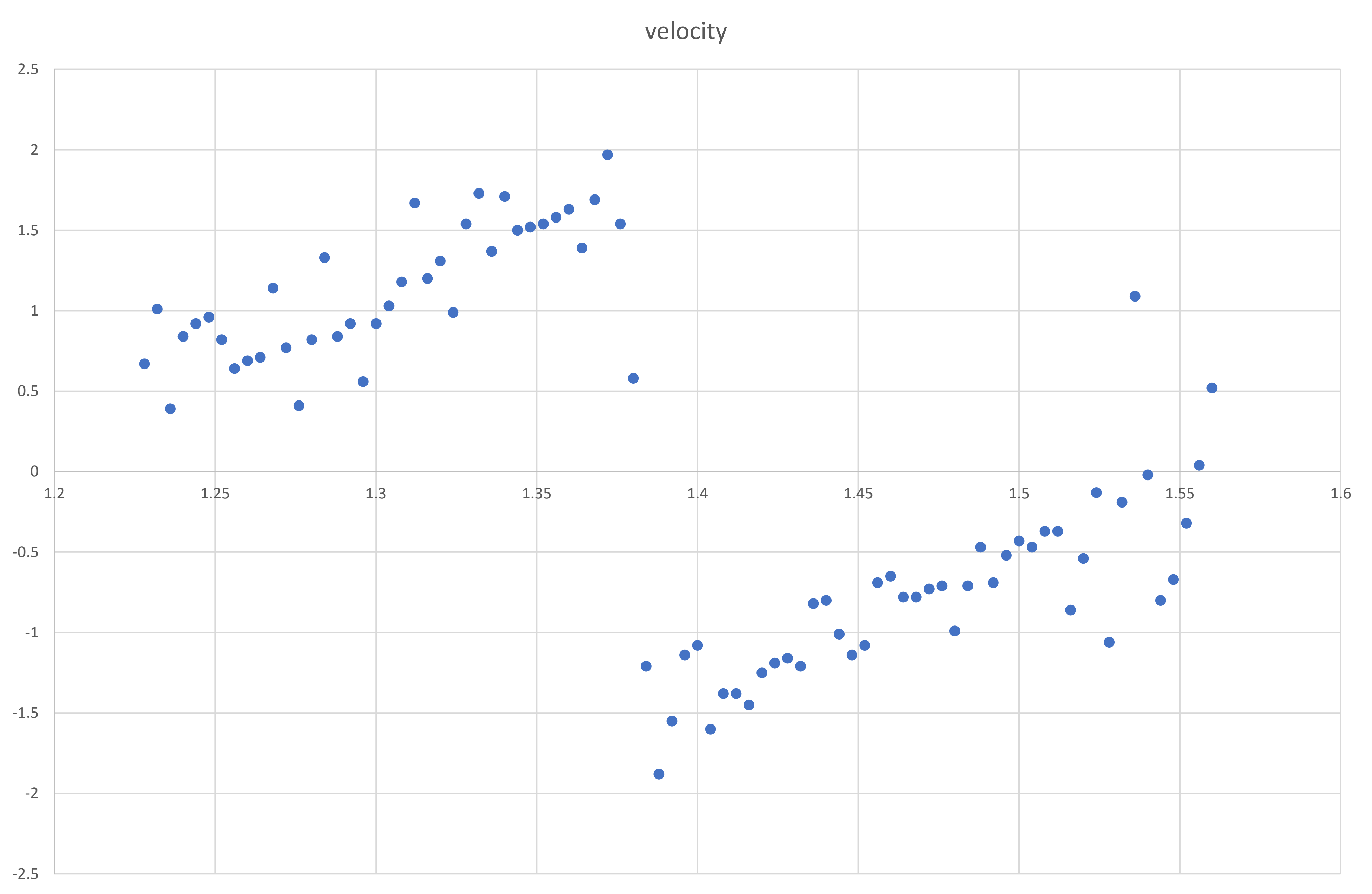


Impulse and Momentums

Theory

- Energy transfers – conservation of energy




velocity
2.5
2
1.5
1
0.5
0
-0.5
-1
-1.5
-2
-2.5
1.2
1.25
1.3
1.35
1.4
1.45
1.5
1.55
1.6

Piezo chip:

- Voltage over time
- Capstone

Voltage (V)	Time (s)
-0.01	2.764
6.83	2.765
9.88	2.766
2.39	2.767
0.47	2.768
0.30	2.769
0.20	2.770
0.15	2.771
0.12	2.772
0.10	2.773
0.08	2.774
0.07	2.775
0.03	2.776
0.03	2.777
0.04	2.778
0.03	2.779
0.03	2.780

Collision Time:
0.016sec or 16ms

Piezo chip:

- Voltage over time
- Capstone