Active Learning Tools in a Physics of Sports Course

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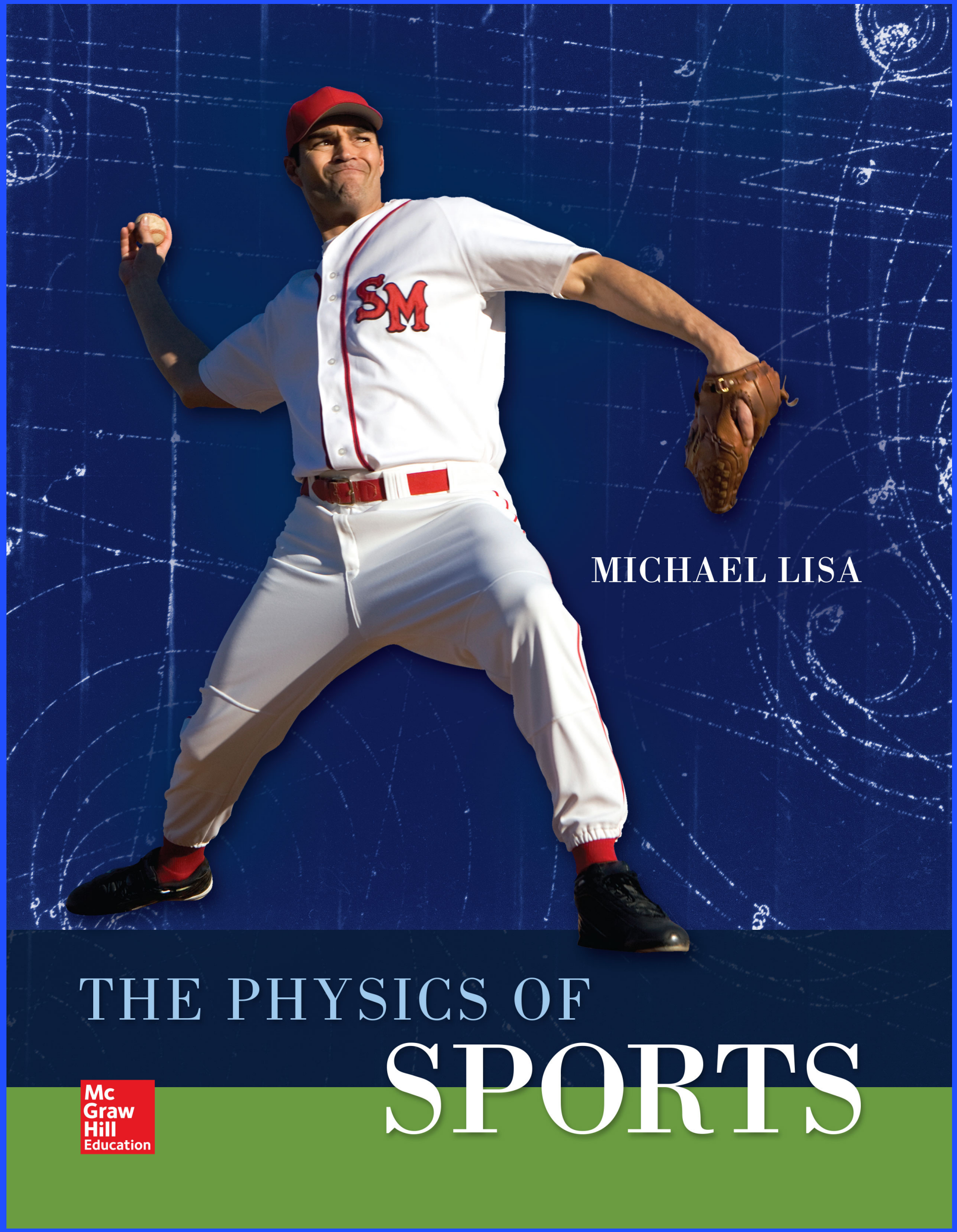


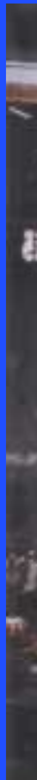
Purpose

- To measure the acceleration of gravity in class as a student activity using tools you already have as part of active learning in a Physics of Sport course

- Determine the limits before drag affects and buoyancy affects come into play.

- Start with a general discussion about the new Physics of Sport Course and slow some learning activities in the classroom.

- Show data demonstrating that we can use an Iphone, available videos on laptops, and a simple 1-2 m scale to measure g within a few percent.



An undergraduate course for Liberal Arts majors

- PHYS 1130 Physics of Sport (3 cr-hrs)

- Textbook: The Physics of Sports, Michael Lisa, McGraw-Hill Education, Copywrite 2016

- Prerequisites: A solid course in trig and algebra . An introductory Physics course at some level is not required but will make life a little easier. Taught twice a year
    - In-person course - Summer Session – meets every day
    - Online course - JTerm (Winter Session) – meets twice a day
    - Typical student is Liberal Arts major

- Course covers a variety of sports and book contains 12 Chapters. I cover only 6 and are mostly on topics such as Center of Mass, Kinematics, Friction, Newtons Laws, Drag force/Crisis, “Magnus” force, Collisions, Impulses, Centripetal acceleration, Angular momentum, COR, etc. applied to a potpouri of athletic performances characterized in the next slide.

- Key point is to solve problems that treat the drag force and Magnus force approximately so that the acceleration is constant. Then you can use the standard kinematic formulas in one and two dimensions at the most.


Ball hit off the sweetspot
Mamadi Diakite
Note the body curve
Don't do this!
Float Serve
Why is this like a knuckleball
VIRGINIA
Kihei Clark
Hang Time
?
C.M Again
Magnus force
Boundary Layer
Follow through
The release
VIRGINIA
20
5
Utilizing C.M
Drag Crisis
Smooth ball
Baseball
Rough ball
Ball speed (mph)
The Low Man Wins
What's a Banana Curve
Centripetal acceleration

Although the surfaces of these balls shown above are quite varied in texture and roughness, there motion in space can be understood in terms of their air drag and magnus lift coefficients and associated forces. This is the direction in which we will go to try to understand the aerodynamics of these projectiles.

- As you will see in the following photos and videos, active learning activities for the students in class have included:

- Determining centripetal acceleration of an orbiting filled glass of fake wine
  - Requires student to follow detailed instructions

- Analyzing dropped ball times over 2 m (0.6389 s) to determine g
  - Requires student to fill out detailed instructions and carefully

- Participating in classroom demonstrations like the low man wins
  and baseball bat vibrations, rotating paper tubes down an incline,

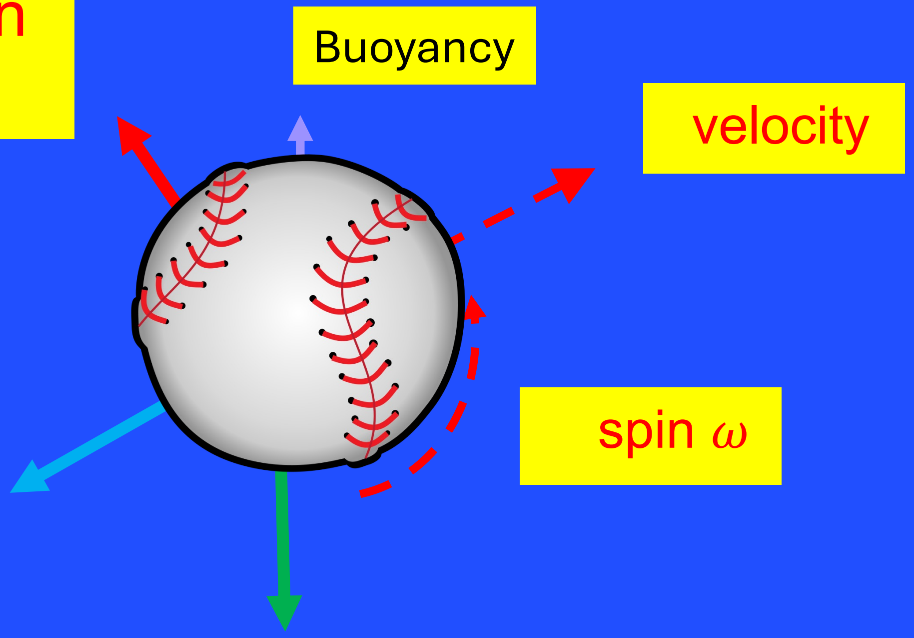
- Fit shooting free throw trajectory data to determine C_D (Drag Coeffient)

The Four (Forces)

$$F = F_g + F_B + F_D + F_M$$

Magnus (Lift) due to spin

$$F_M = \pi^2 C_M \rho R^3 v f$$



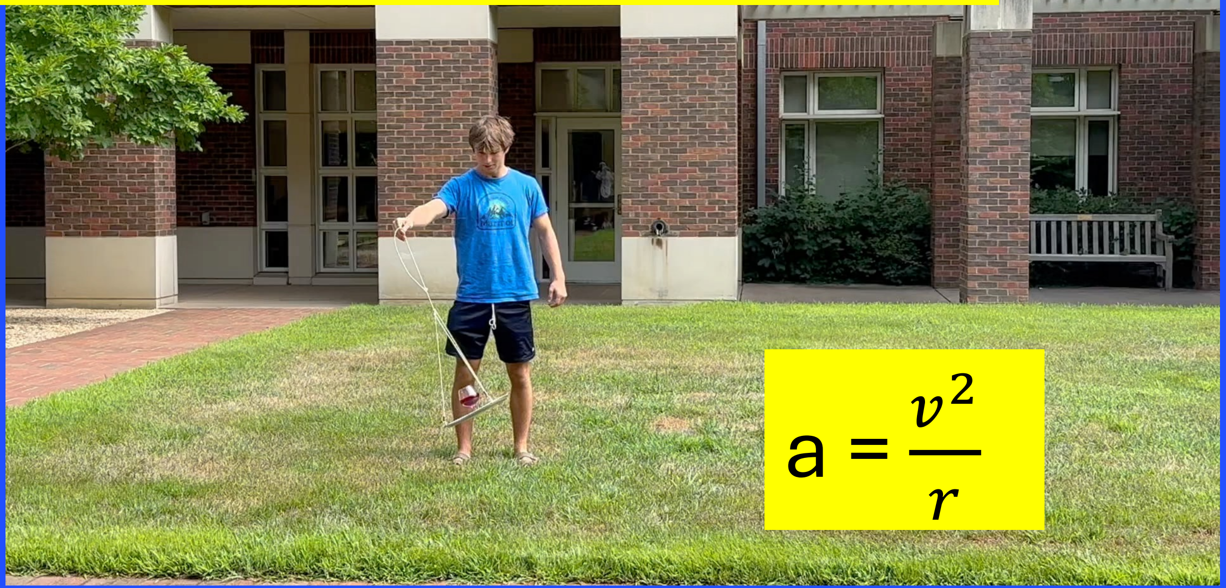
Drag

$$F_D = -\frac{1}{2} C_D (\rho A)(v^2)$$

Gravity and Buoyancy

$F = mg_{eff}$

Measuring swinging frequency and radius of circle to get orbital acceleration



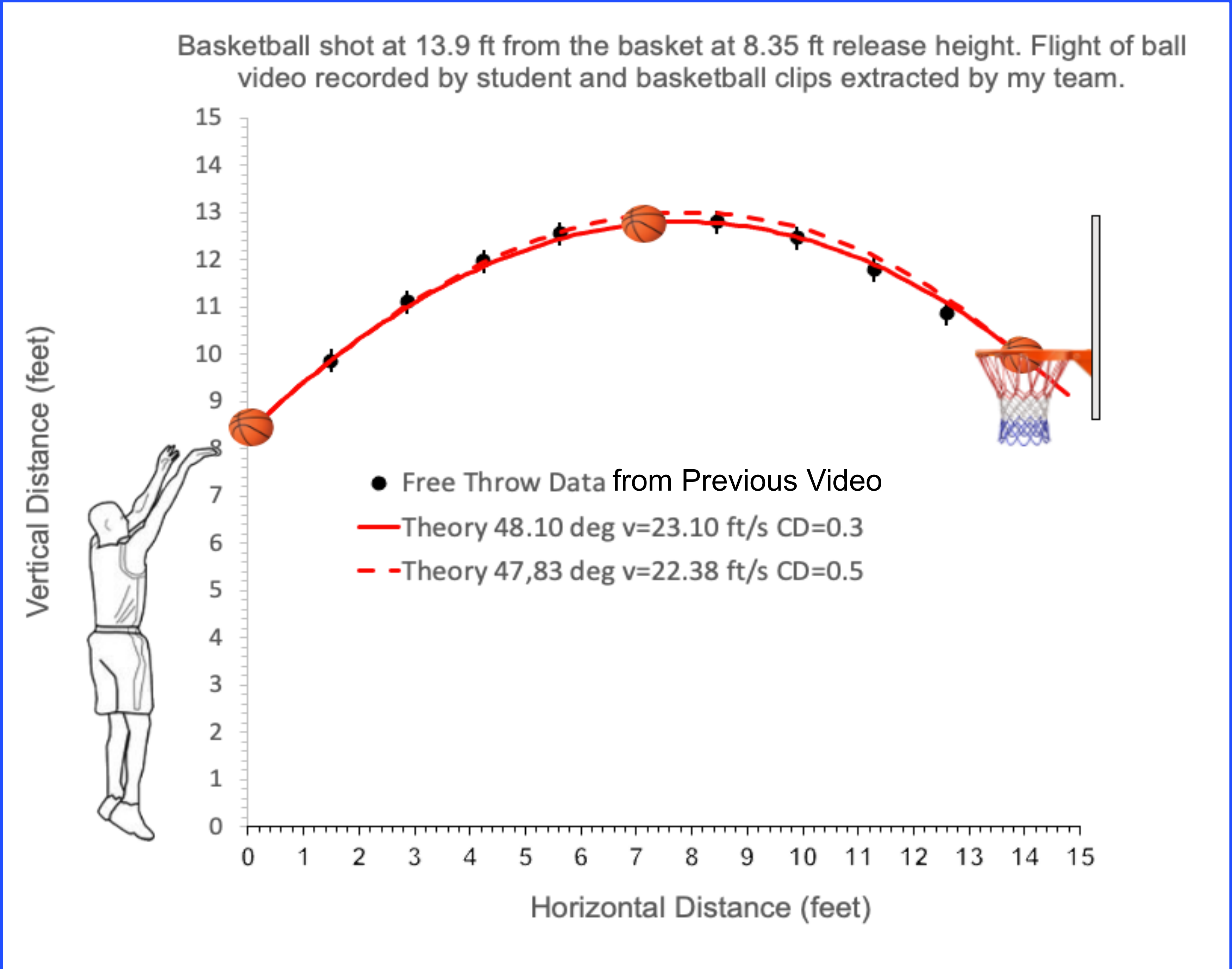
$$a = \frac{v^2}{r}$$

$$g = \frac{2d}{t^2}$$

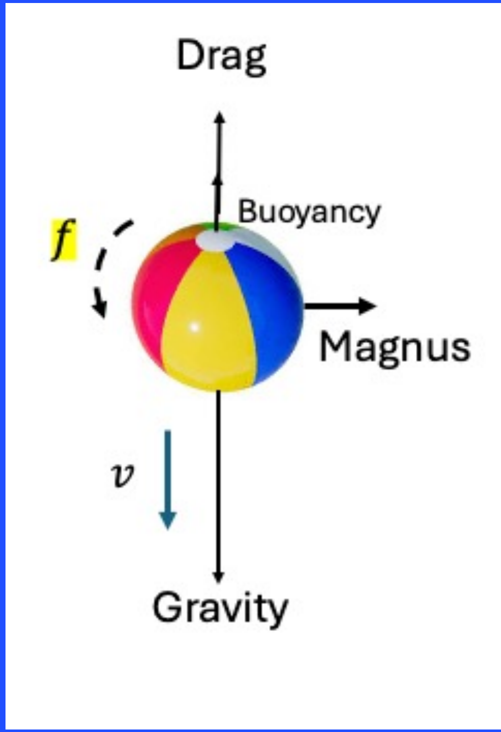
Measuring drop time of pickle ball and ping-pong ball to determine value of g

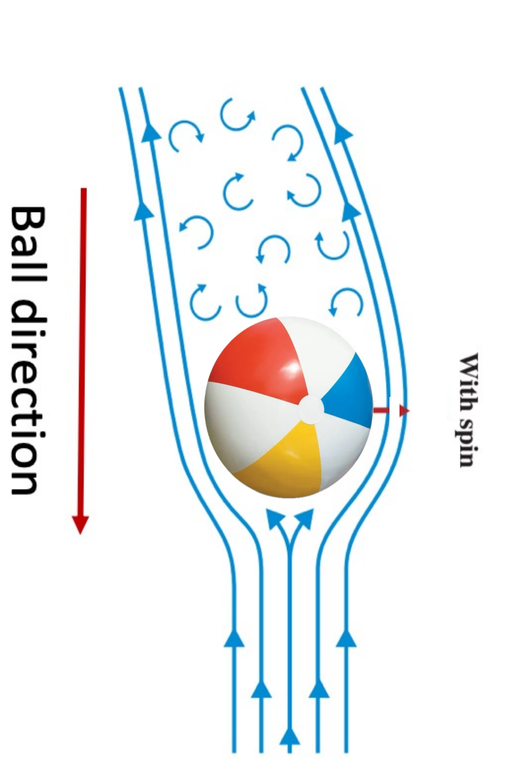
Player from my class being video recorded shooting a Free Throw by another player in the class.

Tracking the basketball from the video of a 6 ft 9 in student from my class shooting a free throw. “Nothing but Net”.

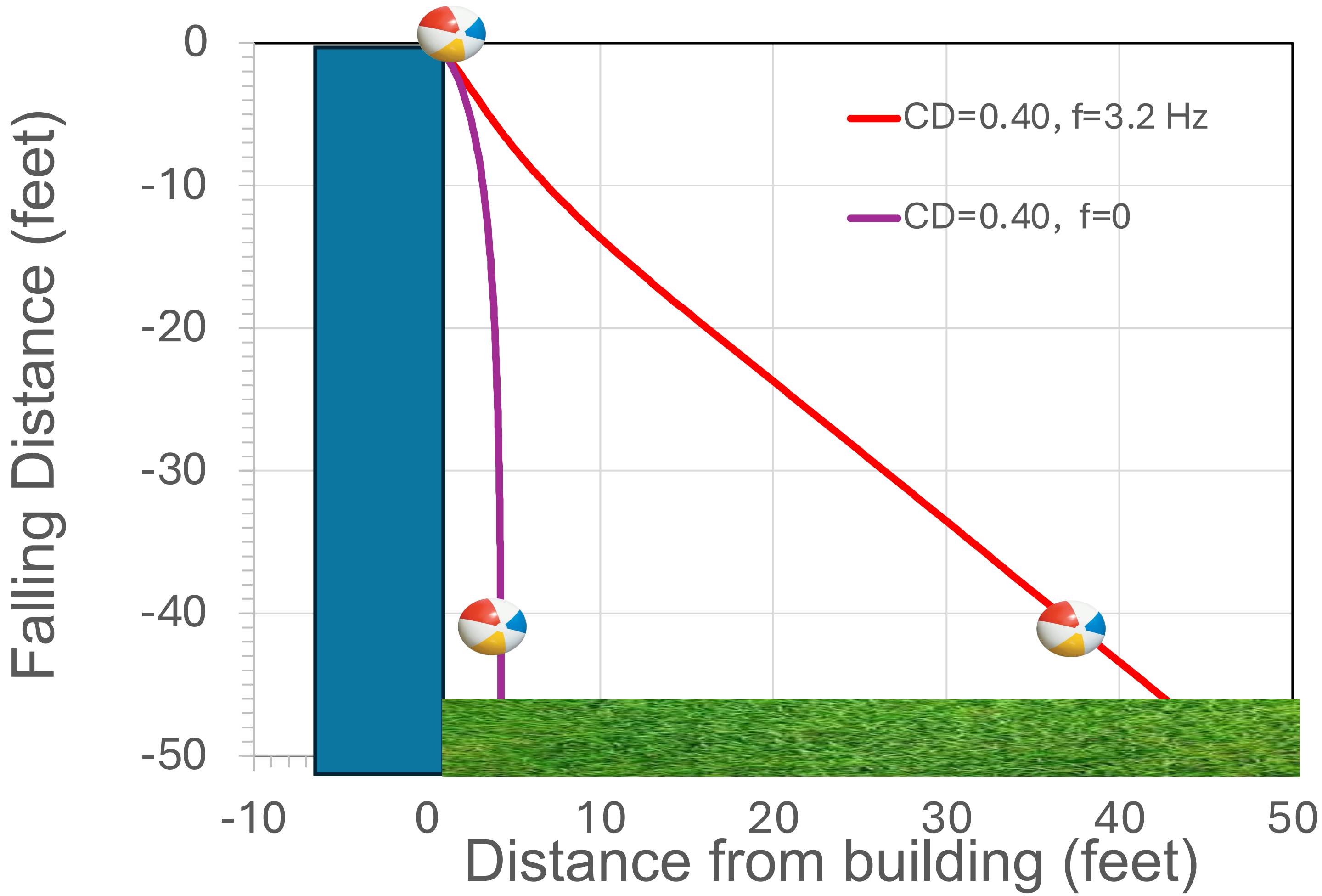

Basketball shot at 13.9 ft from the basket at 8.35 ft release height. Flight of ball video recorded by student and basketball clips extracted by my team.
Vertical Distance (feet)
Horizontal Distance (feet)
15
14
13
12
11
10
9
8
7
6
5
4
3
2
1
0
0
1
2
3
4
5
6
7
8
9
10
11
12
13
14
15
Free Throw Data from Previous Video
Theory 48.10 deg v=23.10 ft/s CD=0.3
Theory 47,83 deg v=22.38 ft/s CD=0.5

Basket Ball Drop


Drag
Buoyancy
f
Magnus
v
Gravity


Ball direction
With spin

24 inch Diameter Beachball Vertical Dropped from UVa Nau Hall 3rd Floor Patio 44ft high (Calculated path from the Four Forces)



• Our intent here is to simplify some activities so that they can be done at home with students taking the online version of the course.

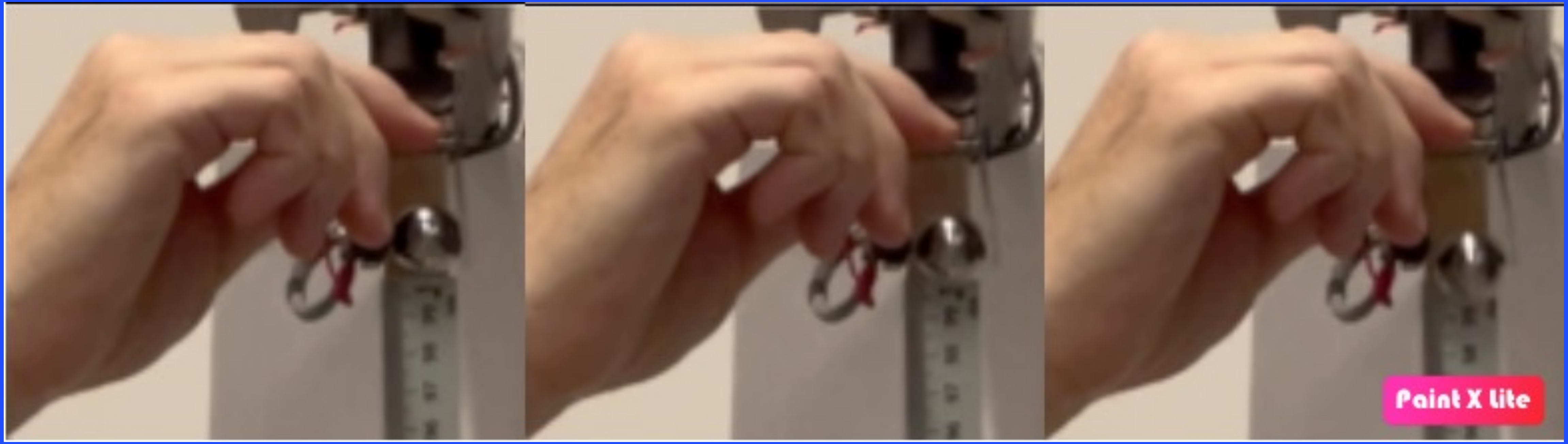
• Now I'll focus on the results for dropping different balls to extract g. And any deviation from g +Buoyancy could be due to the drag force, if the ball is not spinning which is the case for now.

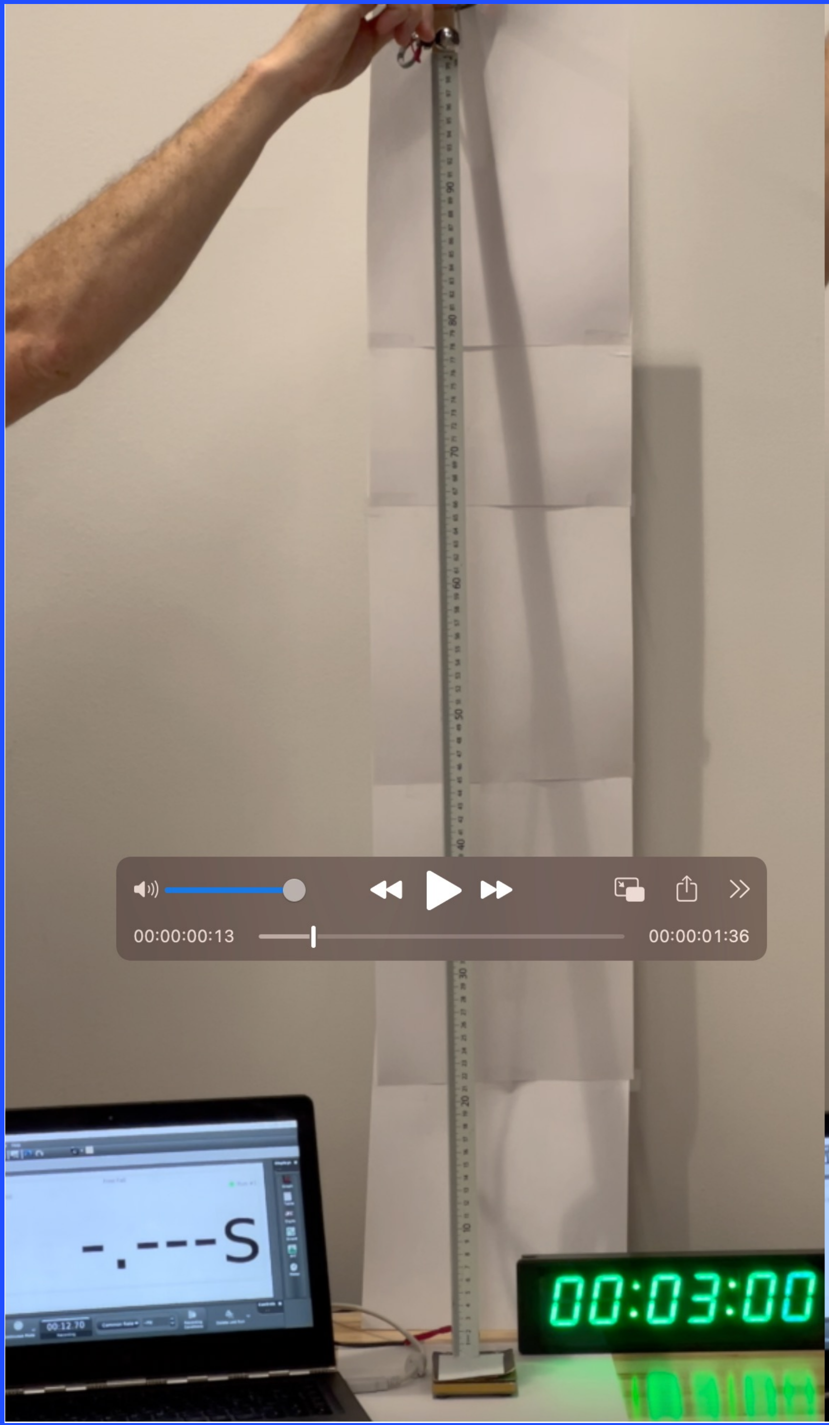
•The buoyant force is well known and can be written as

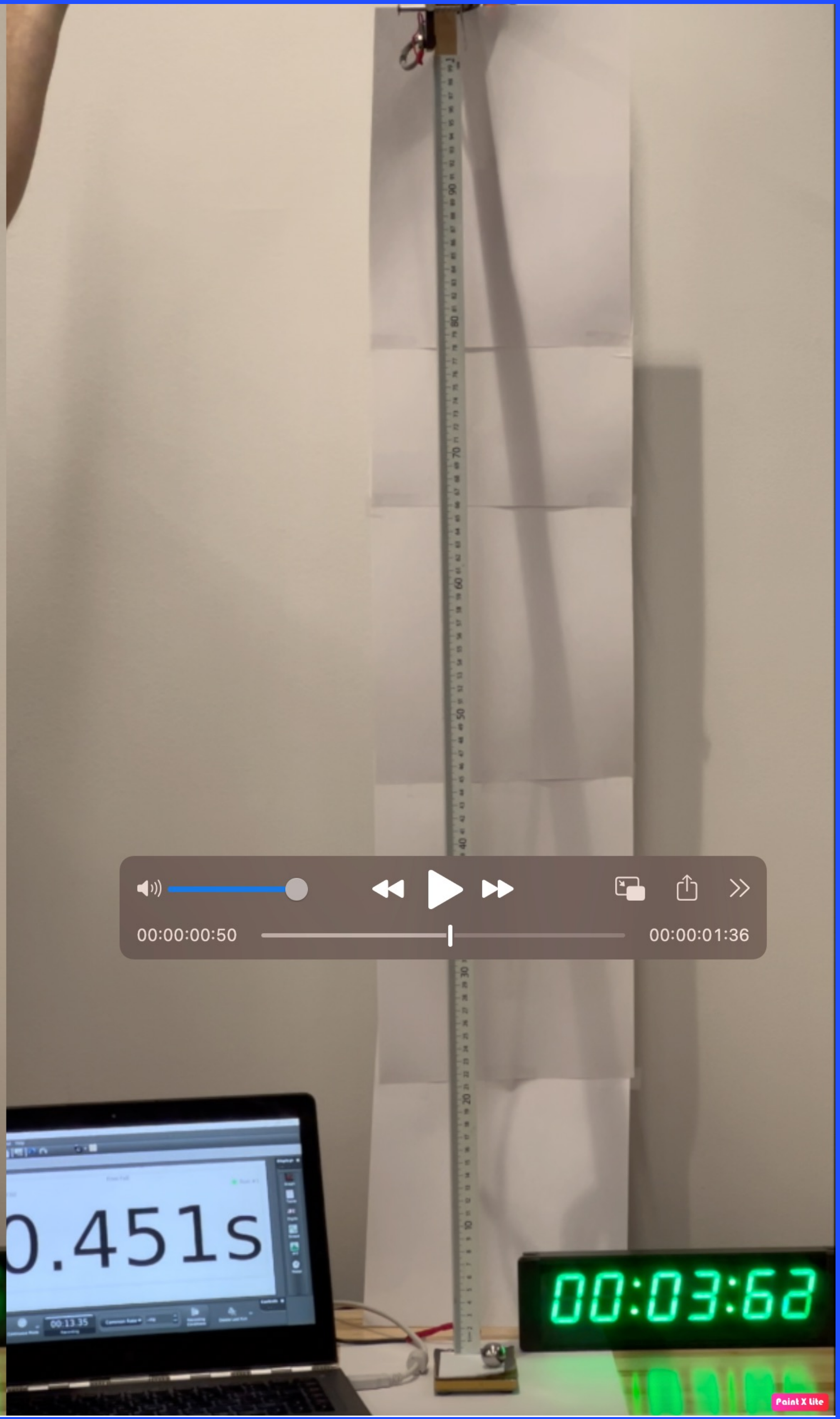
$$g_{eff} = g - \frac{\rho_{air}}{\rho_{ball}} g = g\left(1 - \frac{\rho_{air}}{\rho_{ball}}\right)$$

.The disappointing news is that many balls do not show any deviation from g_{eff} as I will show next mainly because the dropped distance is not long enough to get sufficient speed for large drag.


-.---s
00:02:78


Paint X Lite


00:00:00:13
00:00:01:36
-.---S
00:03:00

00:00:00:40
00:00:01:36
-.---S
00:03:46

00:00:00:50
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.451s
00:03:62


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00:00:02:39
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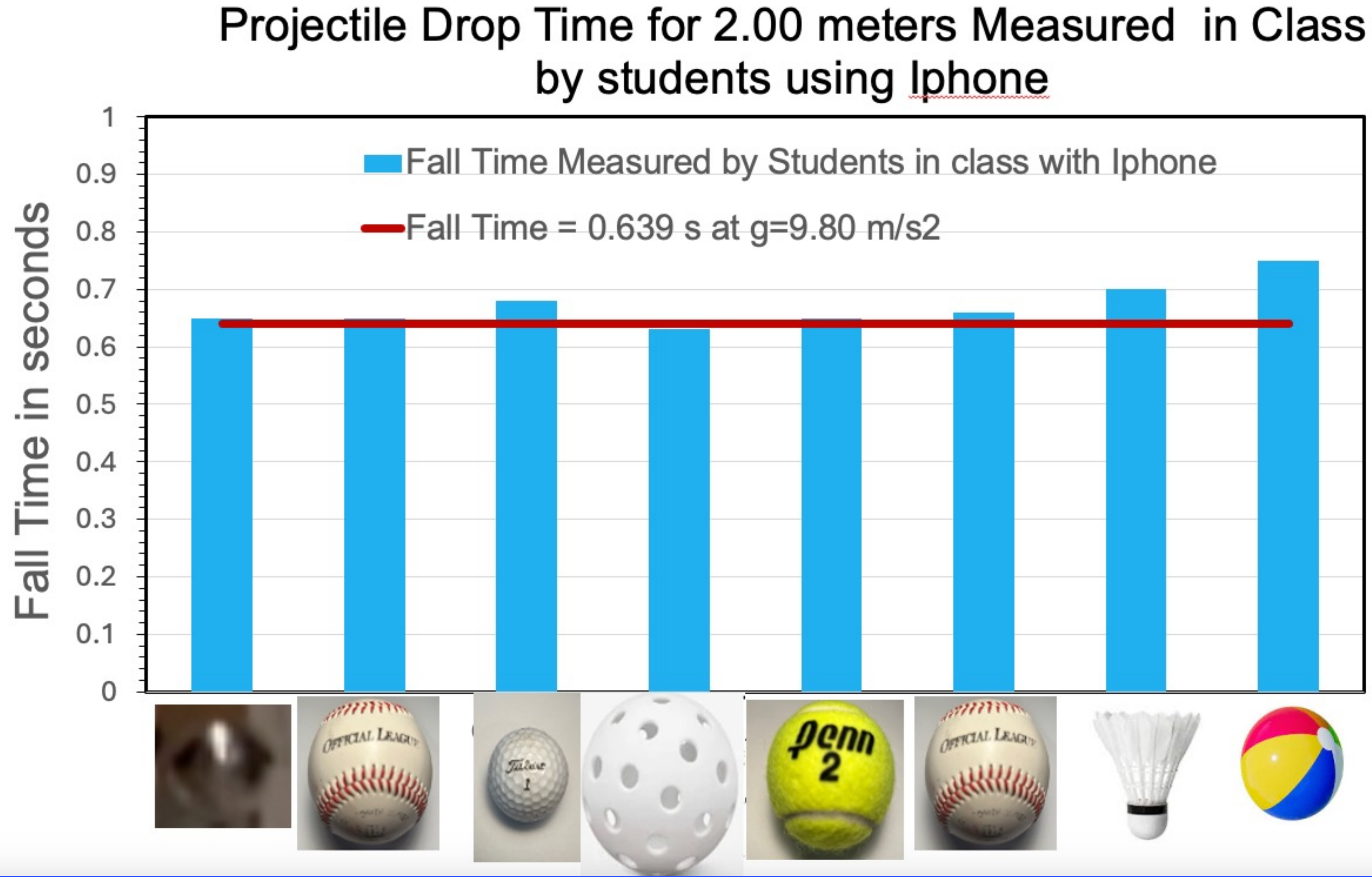
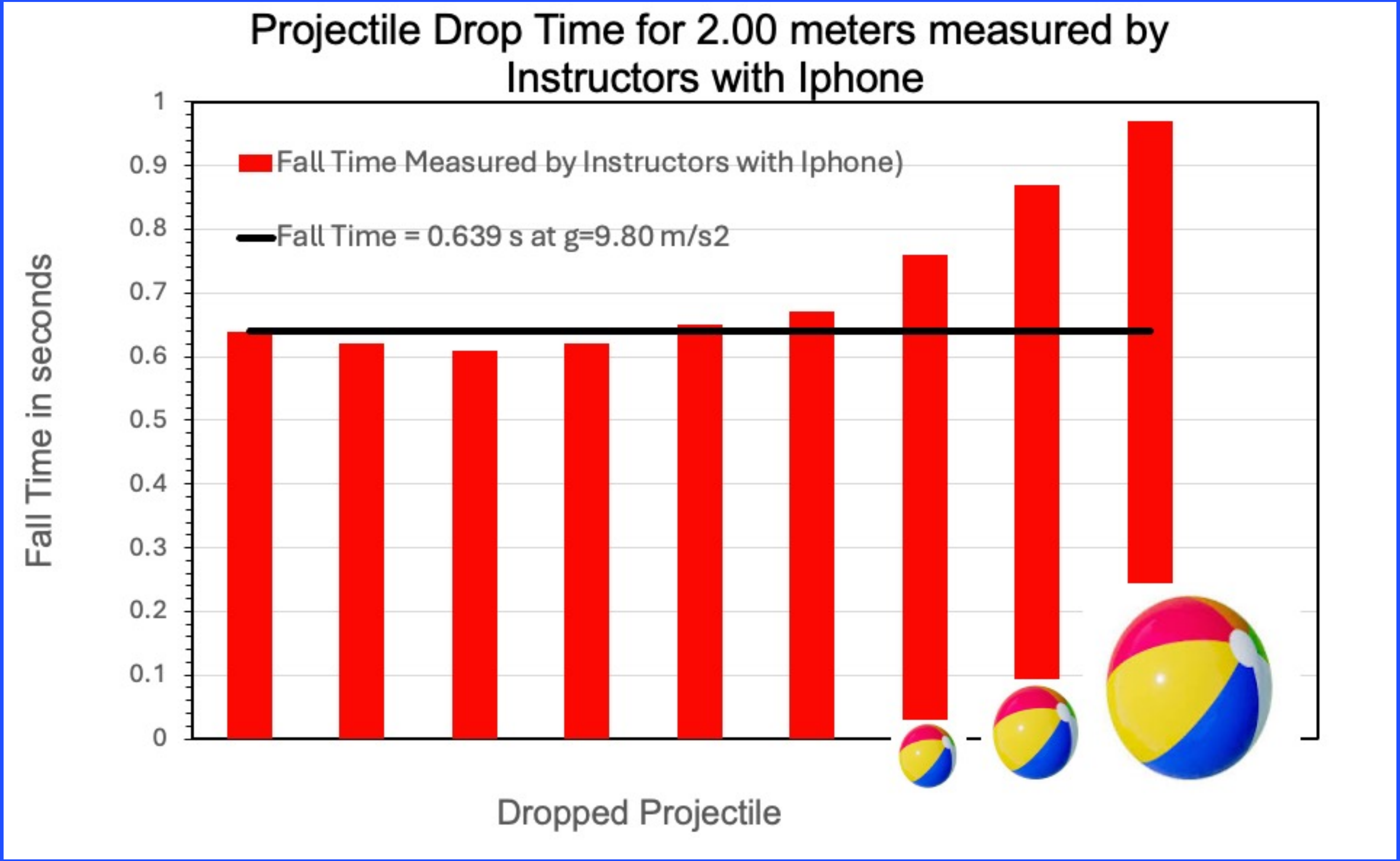
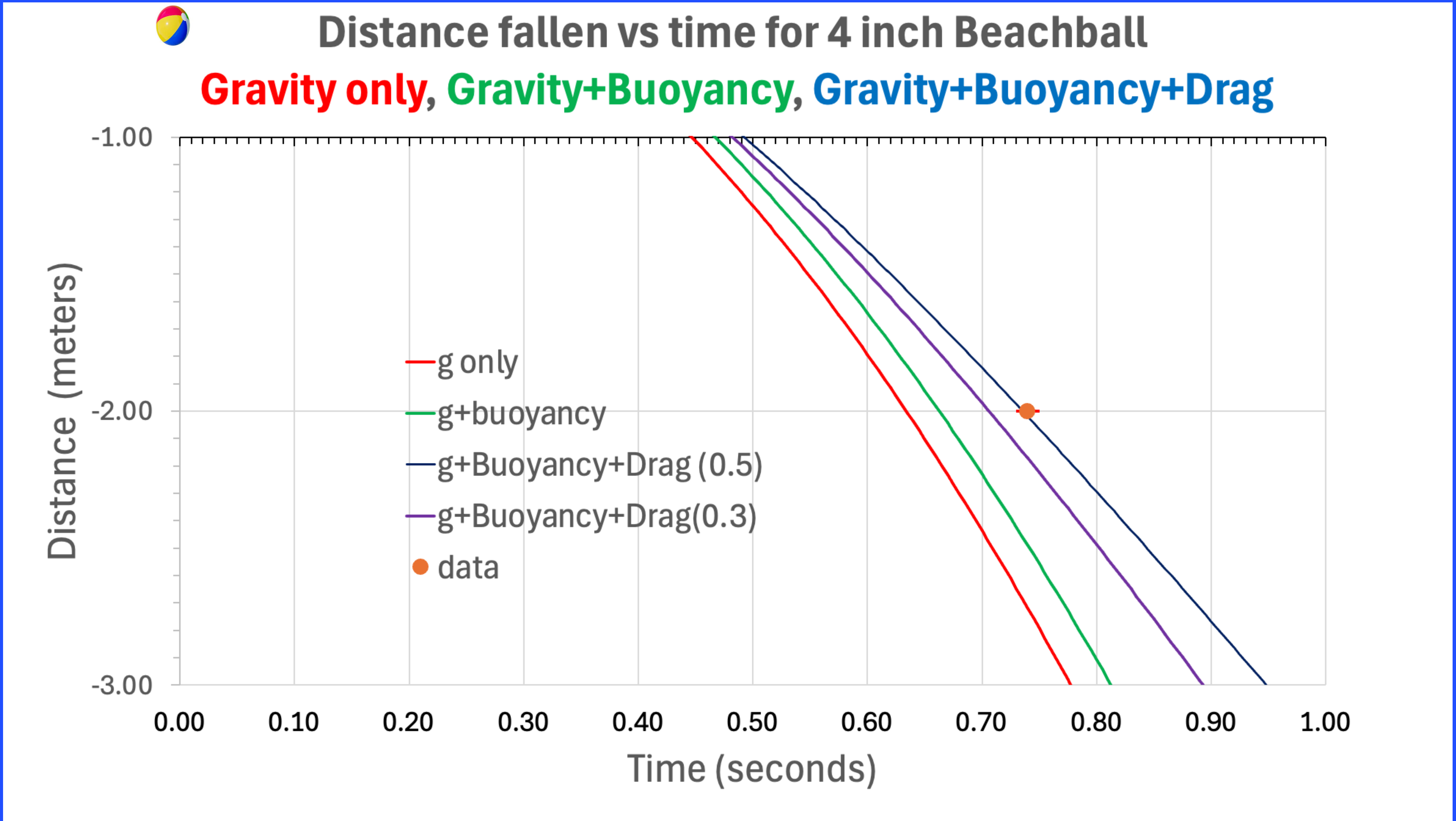
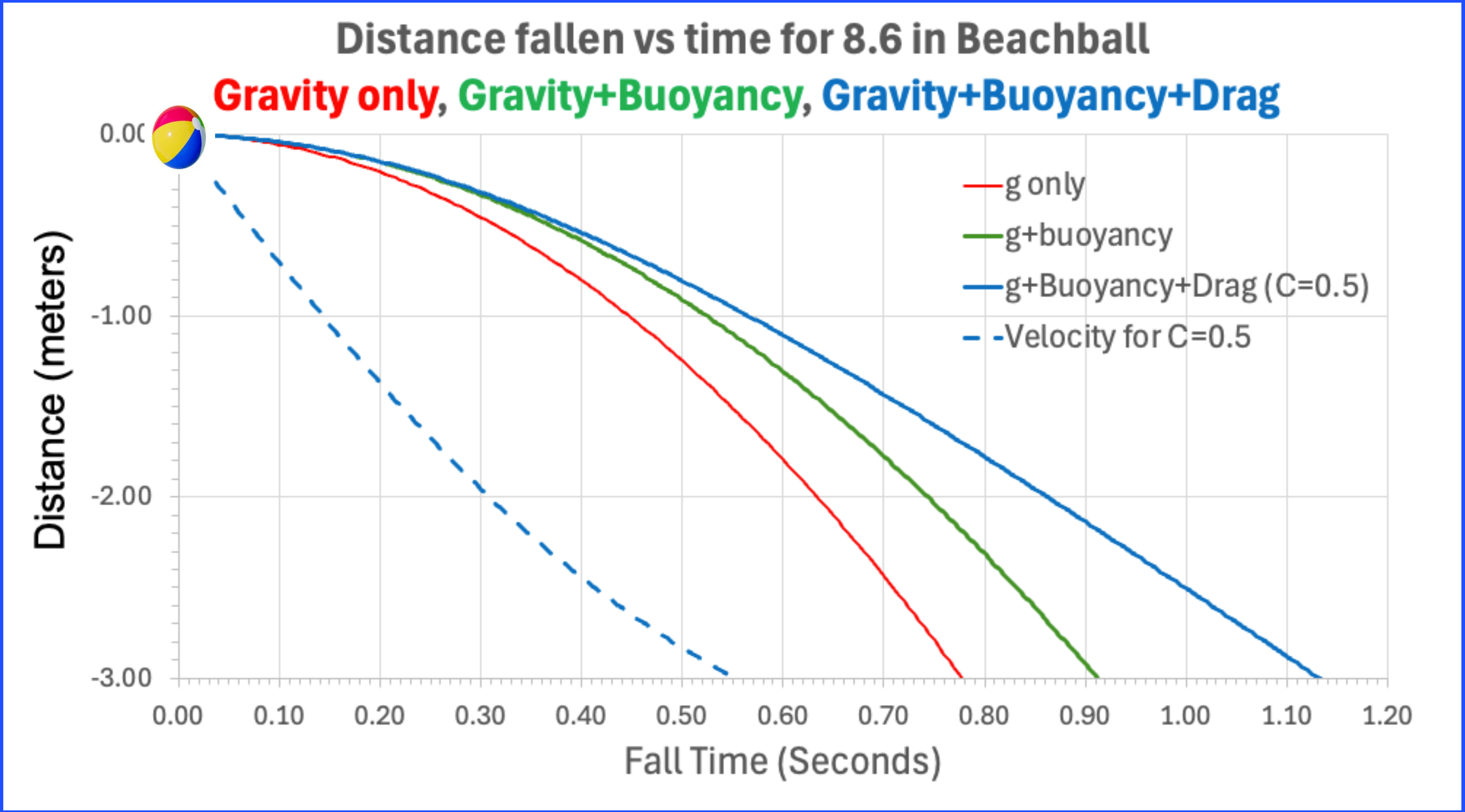
00:14:07


Projectile Drop Time for 2.00 meters Measured in Class by students using Iphone
Fall Time in seconds
1
0.9
0.8
0.7
0.6
0.5
0.4
0.3
0.2
0.1
0
Fall Time Measured by Students in class with Iphone
Fall Time = 0.639 s at g=9.80 m/s2
OFFICIAL LEAGUE
Penn 2


Projectile Drop Time for 2.00 meters measured by Instructors with Iphone
Fall Time Measured by Instructors with Iphone)
Fall Time = 0.639 s at g=9.80 m/s2
Fall Time in seconds
Dropped Projectile
1
0.9
0.8
0.7
0.6
0.5
0.4
0.3
0.2
0.1
0

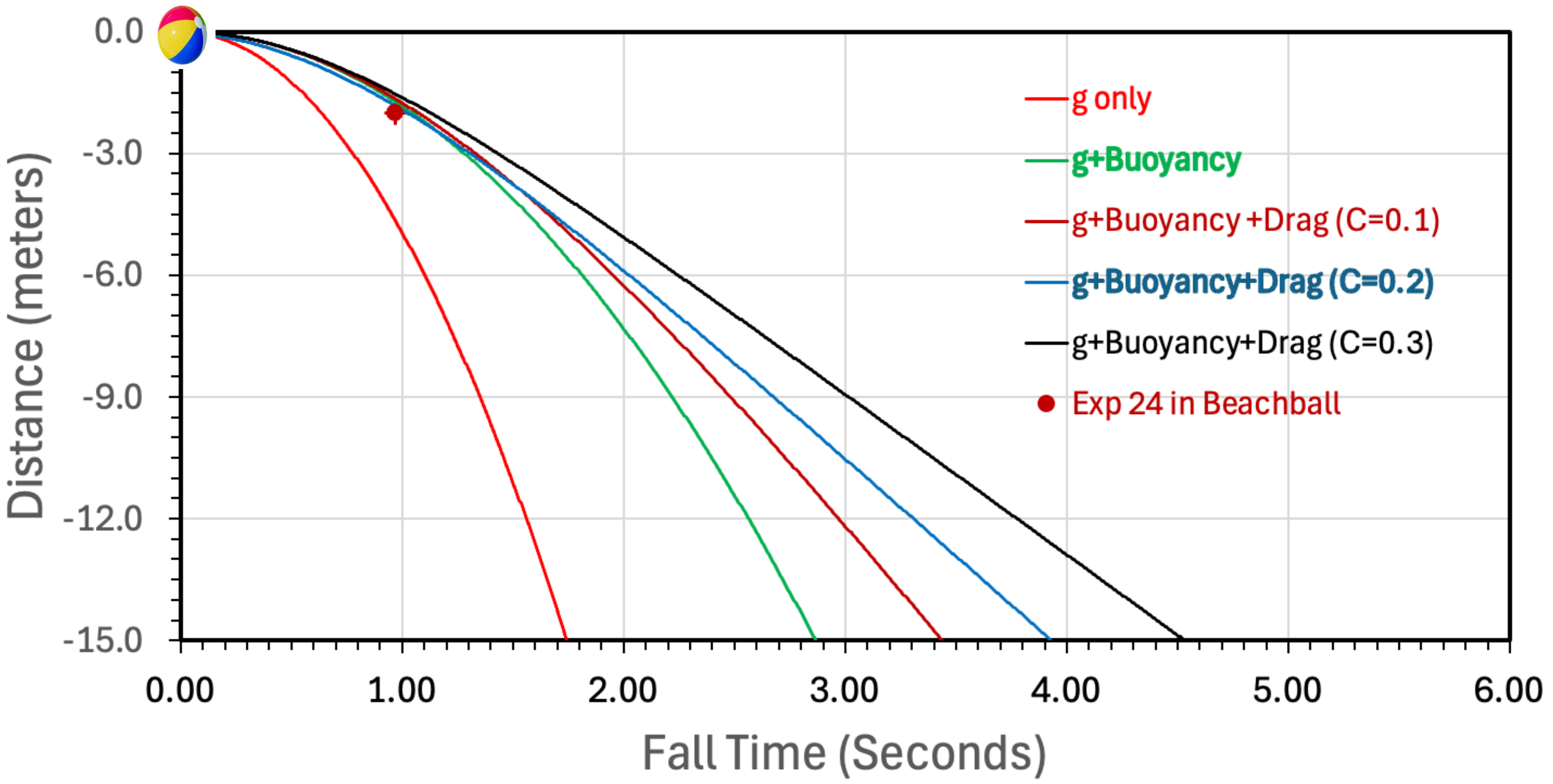


Distance fallen vs time for 4 inch Beachball
Gravity only, Gravity+Buoyancy, Gravity+Buoyancy+Drag
g only
g+buoyancy
g+Buoyancy+Drag (0.5)
g+Buoyancy+Drag(0.3)
data
Distance (meters)
-1.00
-2.00
-3.00
0.00
0.10
0.20
0.30
0.40
0.50
0.60
0.70
0.80
0.90
1.00
Time (seconds)


Distance fallen vs time for 8.6 in Beachball
Gravity only, Gravity+Buoyancy, Gravity+Buoyancy+Drag
-1.00
-2.00
-3.00
Distance (meters)
0.00
0.10
0.20
0.30
0.40
0.50
0.60
0.70
0.80
0.90
1.00
1.10
1.20
Fall Time (Seconds)
g only
g+buoyancy
g+Buoyancy+Drag (C=0.5)
Velocity for C=0.5

Distance fallen vs time for 24 inch Beachball

Gravity only, Gravity+Buoyancy, Gravity+Buoyancy+Drag



Results of Drag Coefficient for 4 in, 8.6 in, and 24 in Beach Balls

Diameter(in)	Distance (m)	Time (s)	Drag Coeff
4 inch	2.00	0.74	0.5
8.6 inch	2.00	0.87	0.5
24 inch	2.00	0.97	undetermined

Summary

1. Students clearly pay significantly more attention when actively engaged and almost sound interested in physics.

2. Measurements of g can be made with a simple cell phone and laptop with uncertainties of the order 20-30 milliseconds in time and of the order of a 1 cm or less in distance.

3. This was sufficient to get a meaningful measurement of g (few percent) by students in the class room for all balls tested except the beachball.

4. Further activities will be explored including increasing the fall fall distance to clearly identify and distinguish the difference between drag and buoyancy effects.

- Acknowledgements
  - Ying Lindgren – video recorder/analyzer/editing
  - student athlete who made free throw video available
  - class members