Active Learning Tools in a Physics of Sports Course

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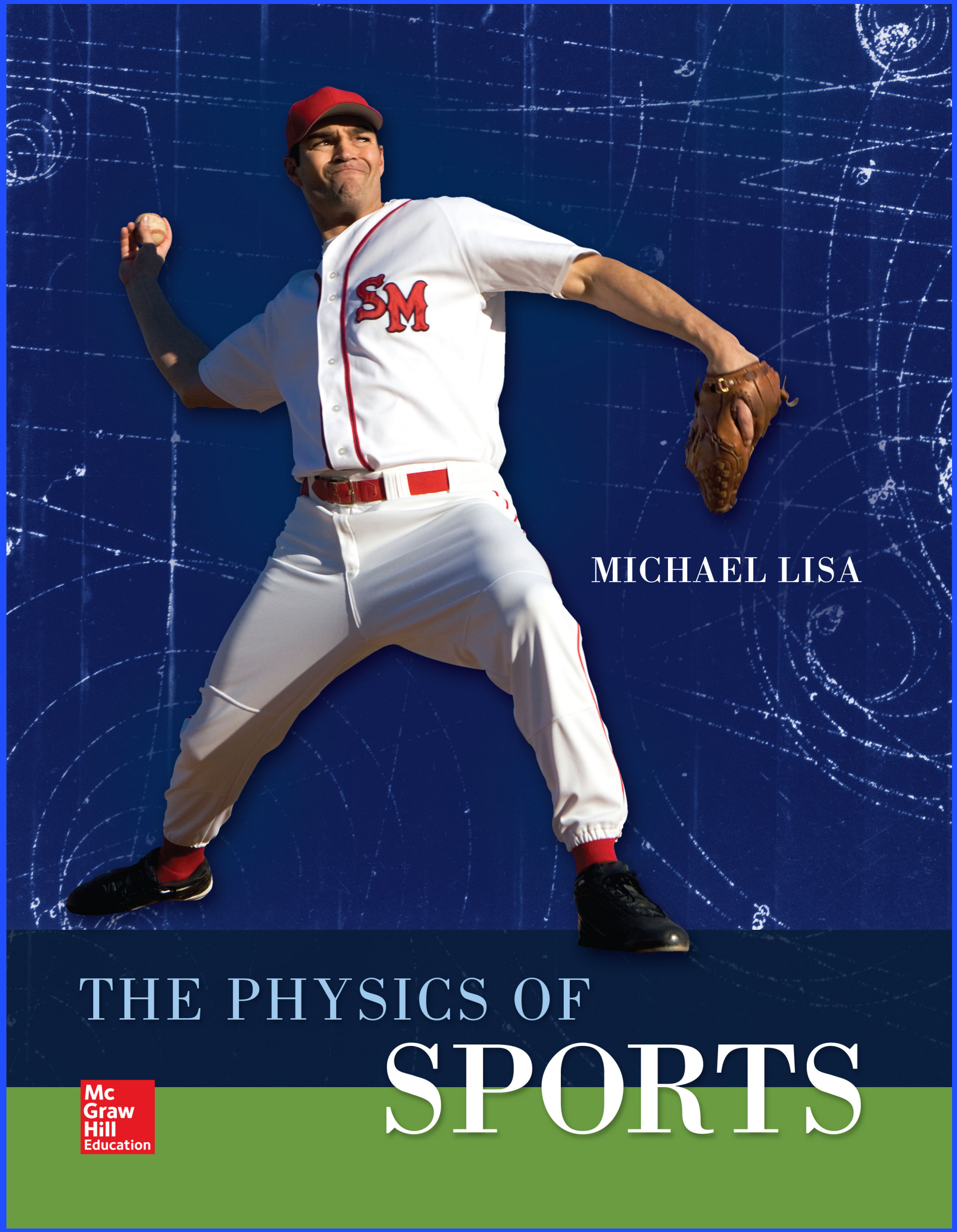


Introduction

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

- One activity is to have the students determine the acceleration of gravity g by simply dropping a ball from rest in class using either available or inexpensive tools as part of an active learning environment in our Physics of Sport class. Students take the measurements and analyze the data.

- We will show the kinematic limits at which you can determine g before drag and buoyancy affects have to be considered. I use an excel spread sheet type calculation with hundreds of iterative finite size steps to calculate out the required calculations that include the drag force.

- Show data demonstrating that we can use an Iphone, do video analysis on a laptop to measure time, and a simple 1-2 m scale to measure g within a few percent. Recall $g = \frac{2d}{t^2}$.

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
Kihei Clark
?
C.M Again
Hang Time
Follow through
Magnus force
Boundary Layer
The release
Utilizing C.M
The Low Man Wins
What's a Banana Curve
Drag Crisis
Smooth ball
Baseball
Rough ball
Centripetal acceleration

Some of the balls we use to drop and determine g.

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.

- Some examples of 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, baseball bat vibrations, rotating paper tubes down an incline,etc.

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

Physics Formulas

The Four (Forces)

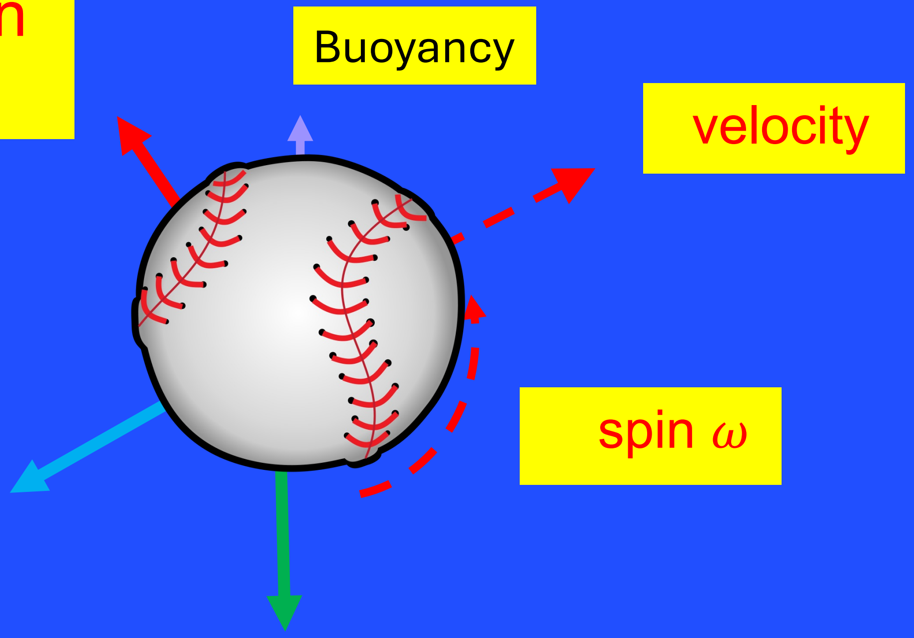
$$F = F_g + F_B + F_D + F_M$$

Magnus (Lift) due to spin

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

Drag

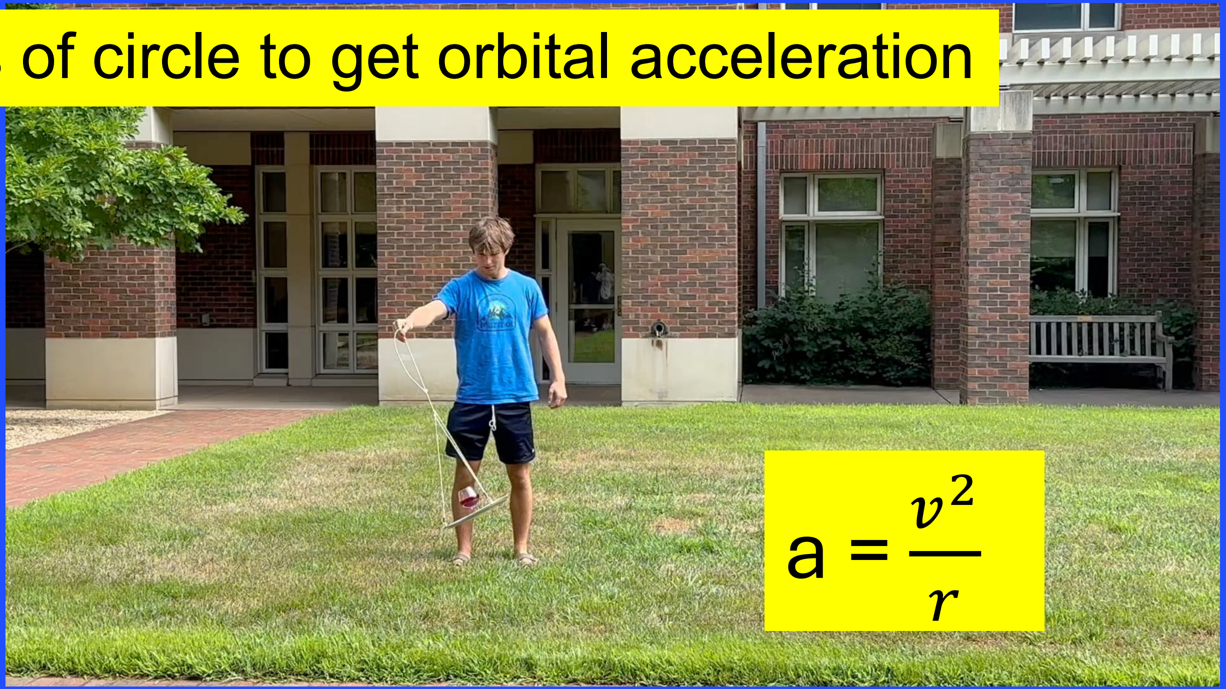
$$F_D = -\frac{1}{2} C_D (\rho A)(v^2)$$



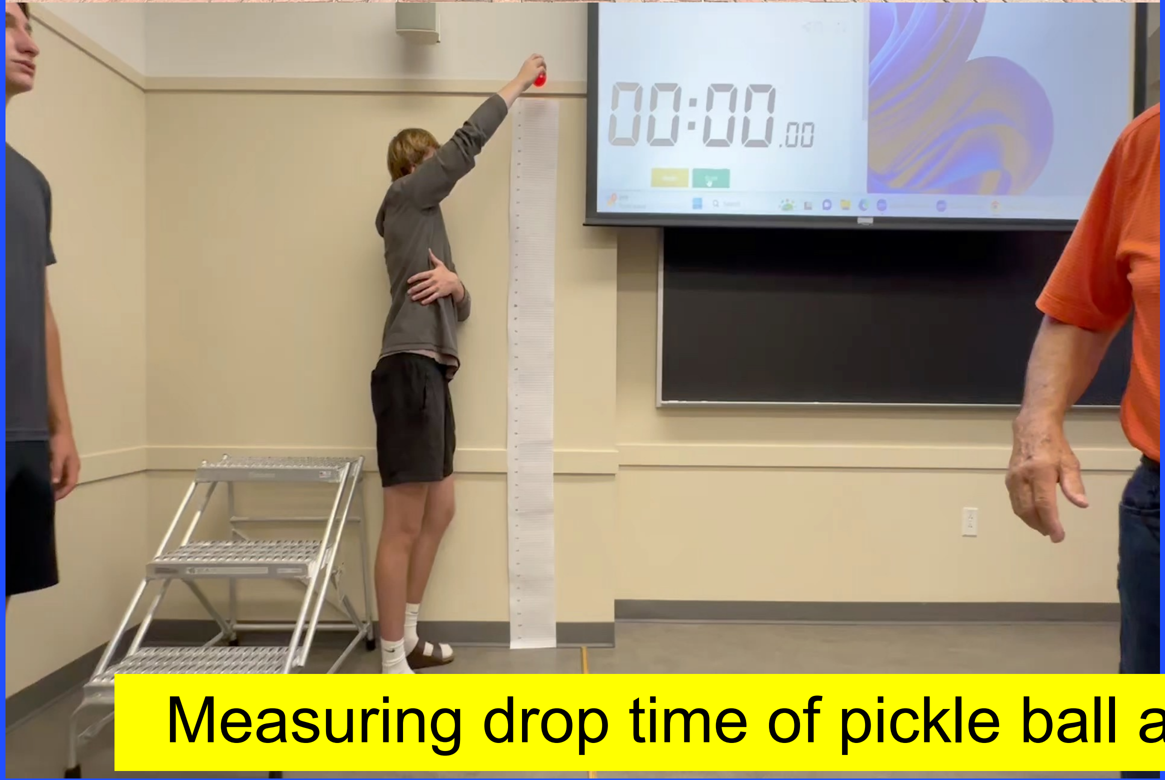
Gravity and Buoyancy

$$F = mg_{eff}$$

Measuring swinging frequency and radius of circle to get orbital acceleration



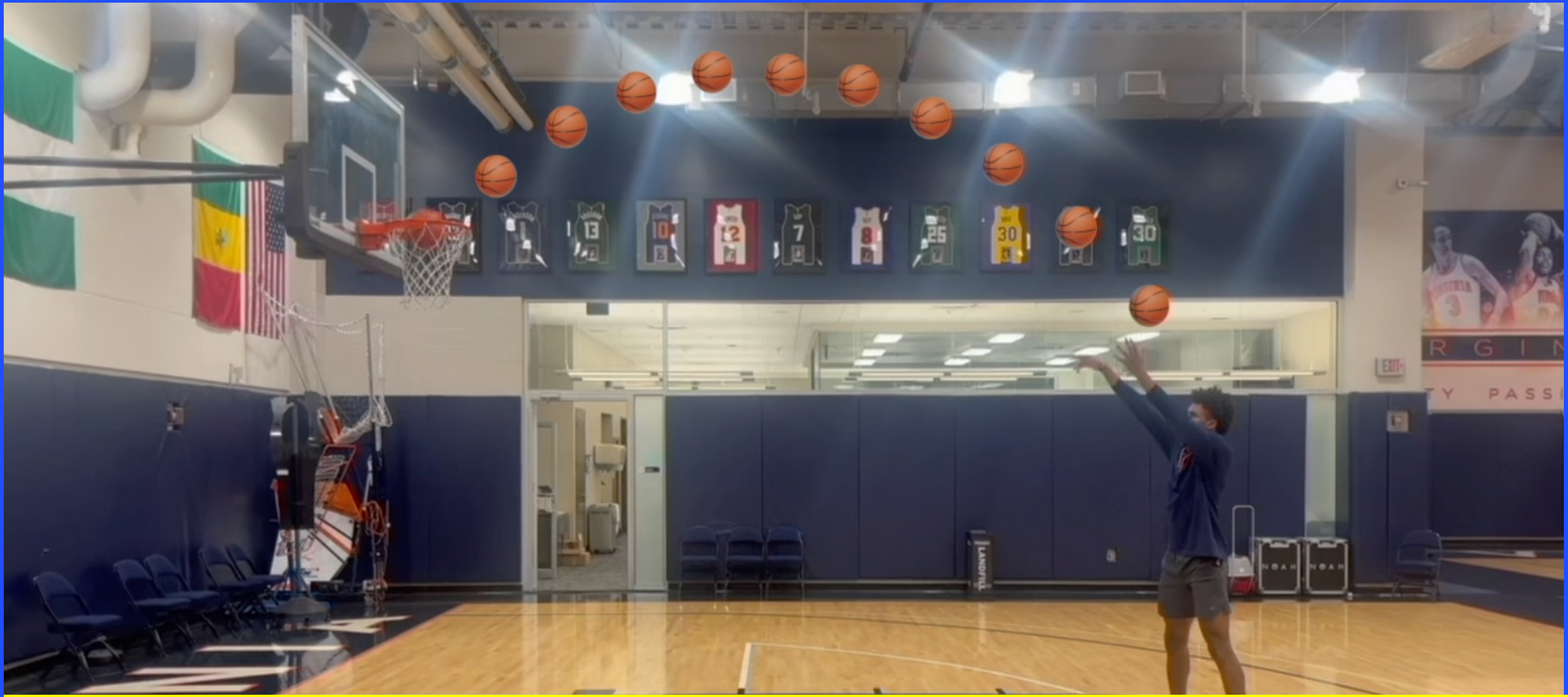
$$a = \frac{v^2}{r}$$



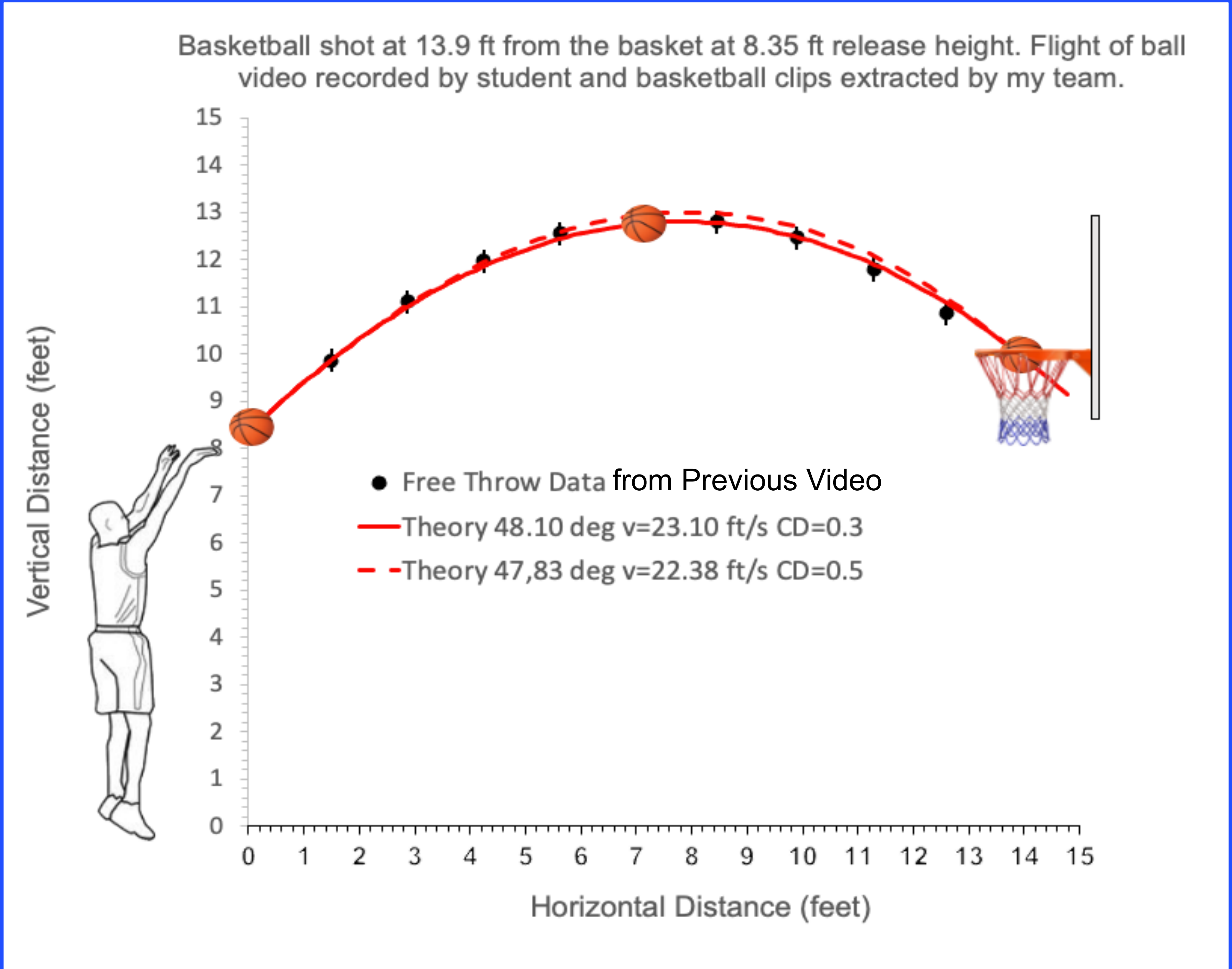
$$g = \frac{2d}{t^2}$$

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

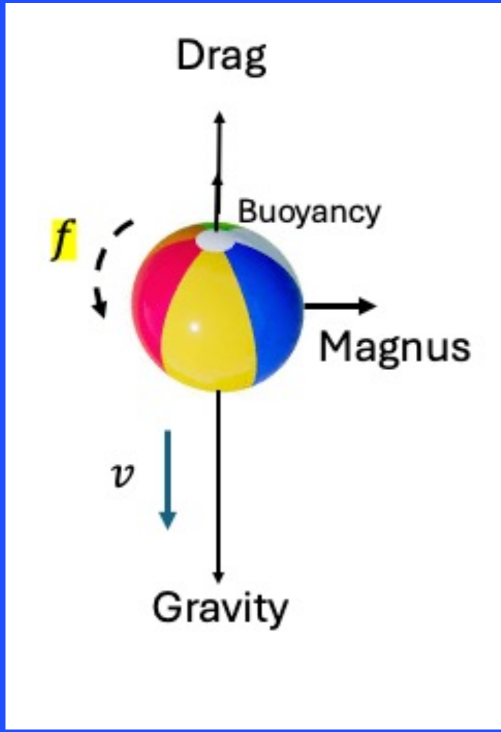
Player from my class being video recorded shooting a Free Throw by another player in the class.

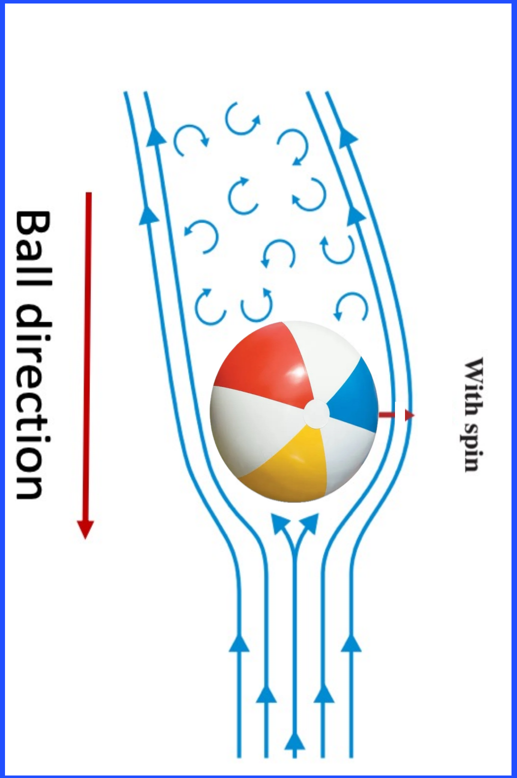


Tracking the basketball from the video of a 6 ft 9 in student from my class shooting a free throw. “Nothing but Net”.

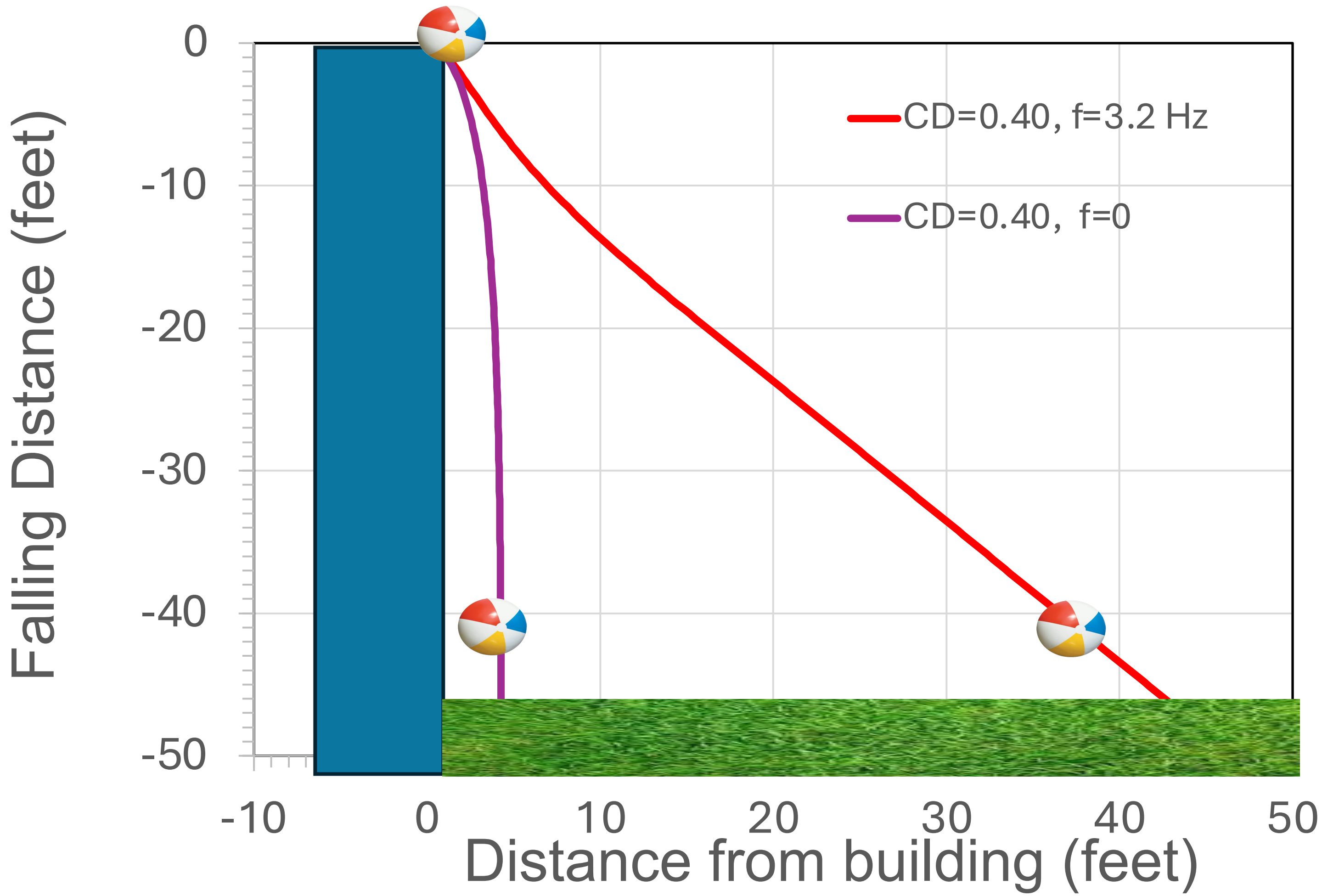


Basketball shot at 13.9 ft from the basket at 8.35 ft release height. Flight of ball video recorded by student and basketball clips extracted by my team.
Vertical Distance (feet)
15
14
13
12
11
10
9
8
7
6
5
4
3
2
1
0
0 1 2 3 4 5 6 7 8 9 10 11 12 13 14 15
Horizontal Distance (feet)
Free Throw Data from 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


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

• In a moment I'll some results for determining g by dropping different balls. And any deviation from g +Buoyancy could be due to the drag force, if the ball is not spinning which is now the case.

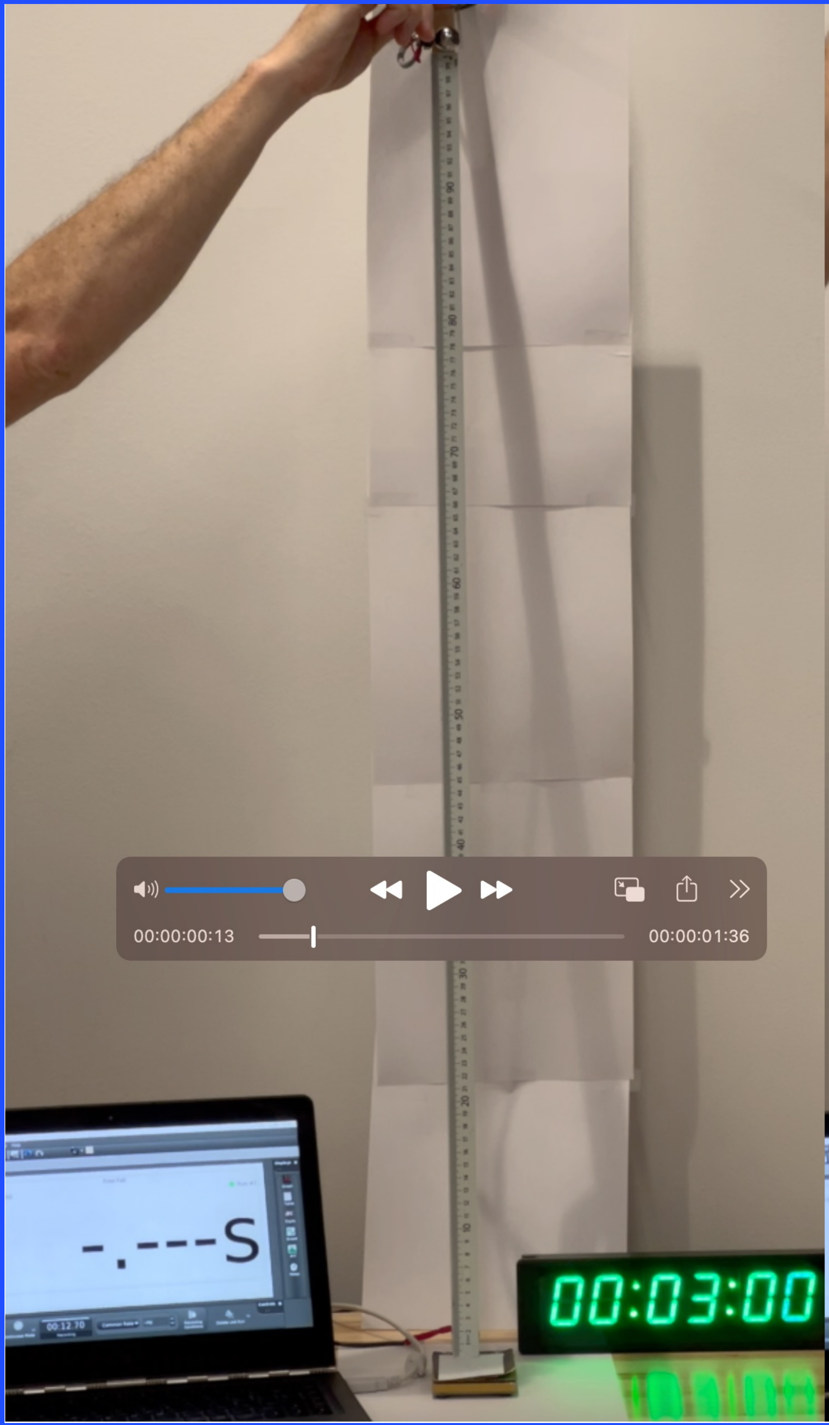
•The buoyant force is well known and is the first correction we must make to extracr g correctly or confirm it is negligible.

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

.Here is example of how measurements are performed and a check on the accuracy of our timing by Dr. Al Tobias.


-.---S
00:02:78


Paint X Lite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00:00:01:36
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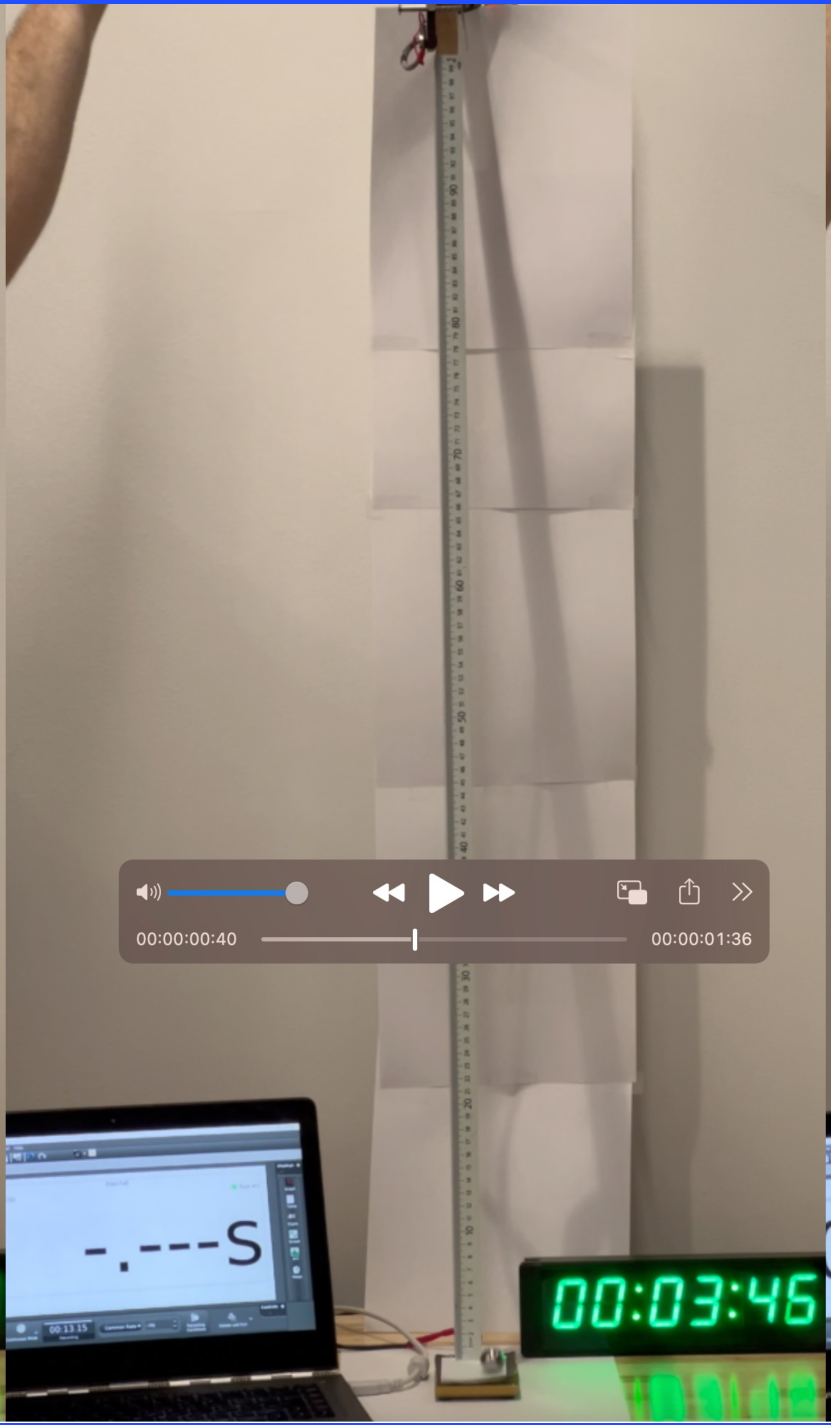
00:03:00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00:00:01:36
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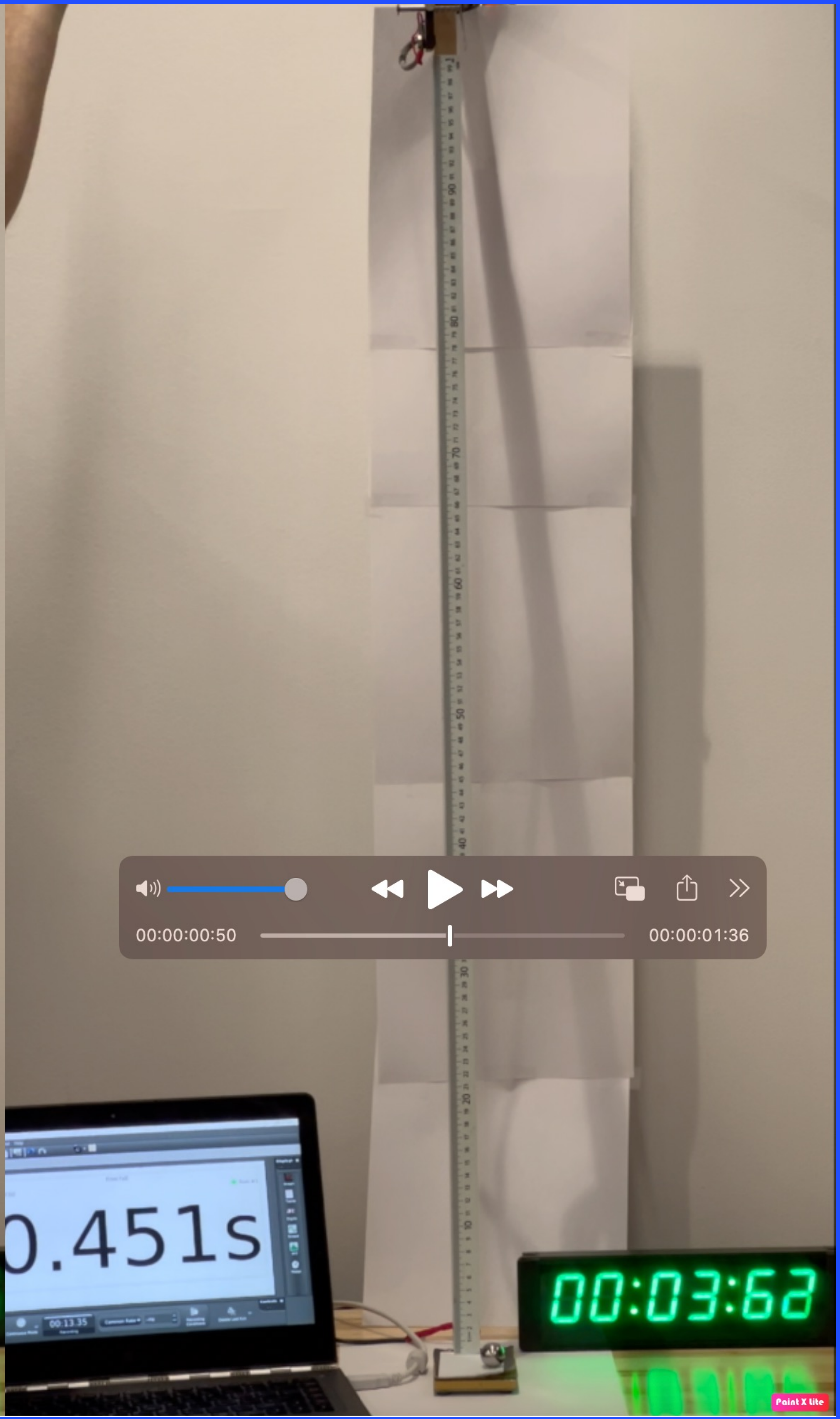
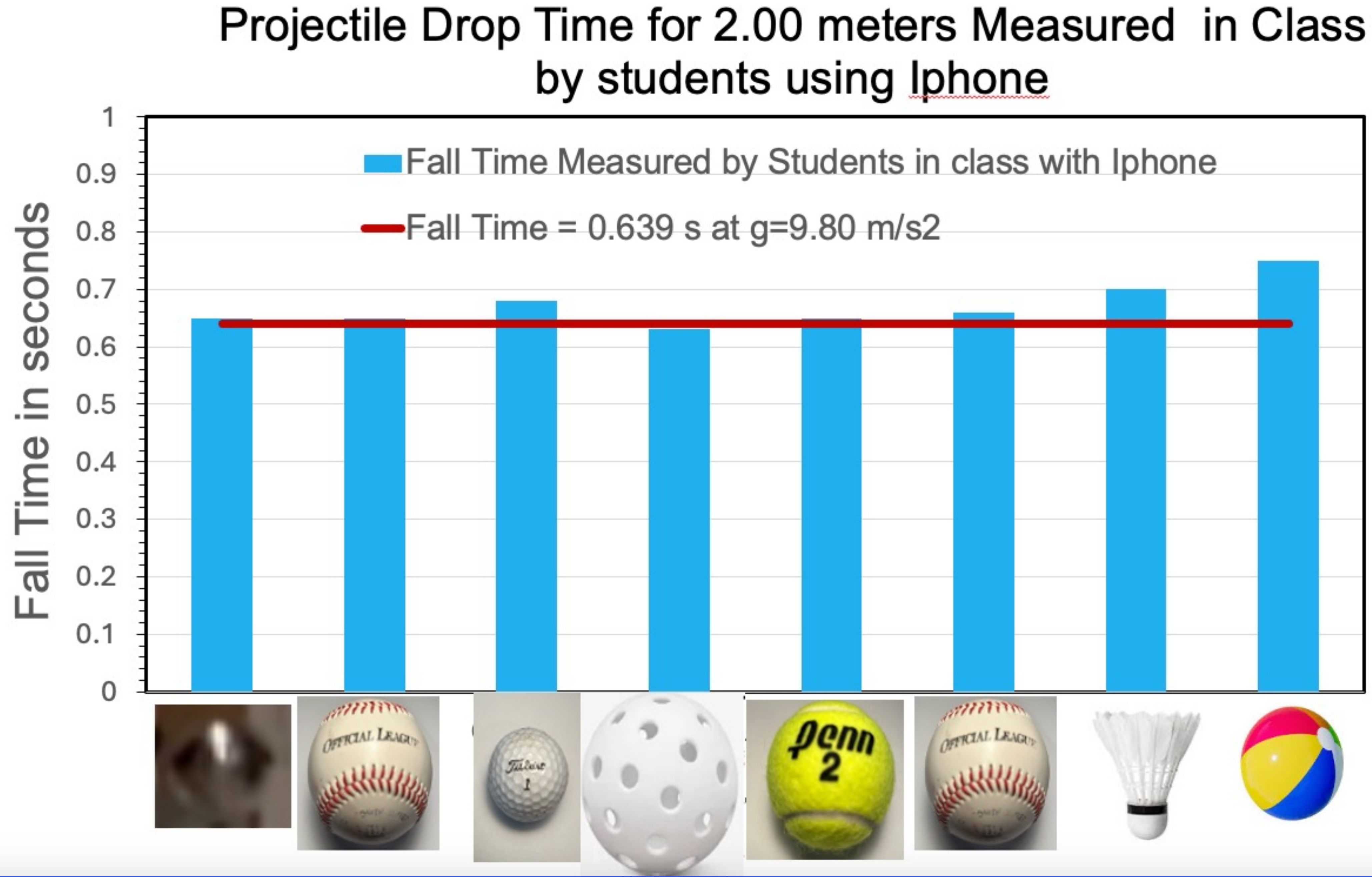
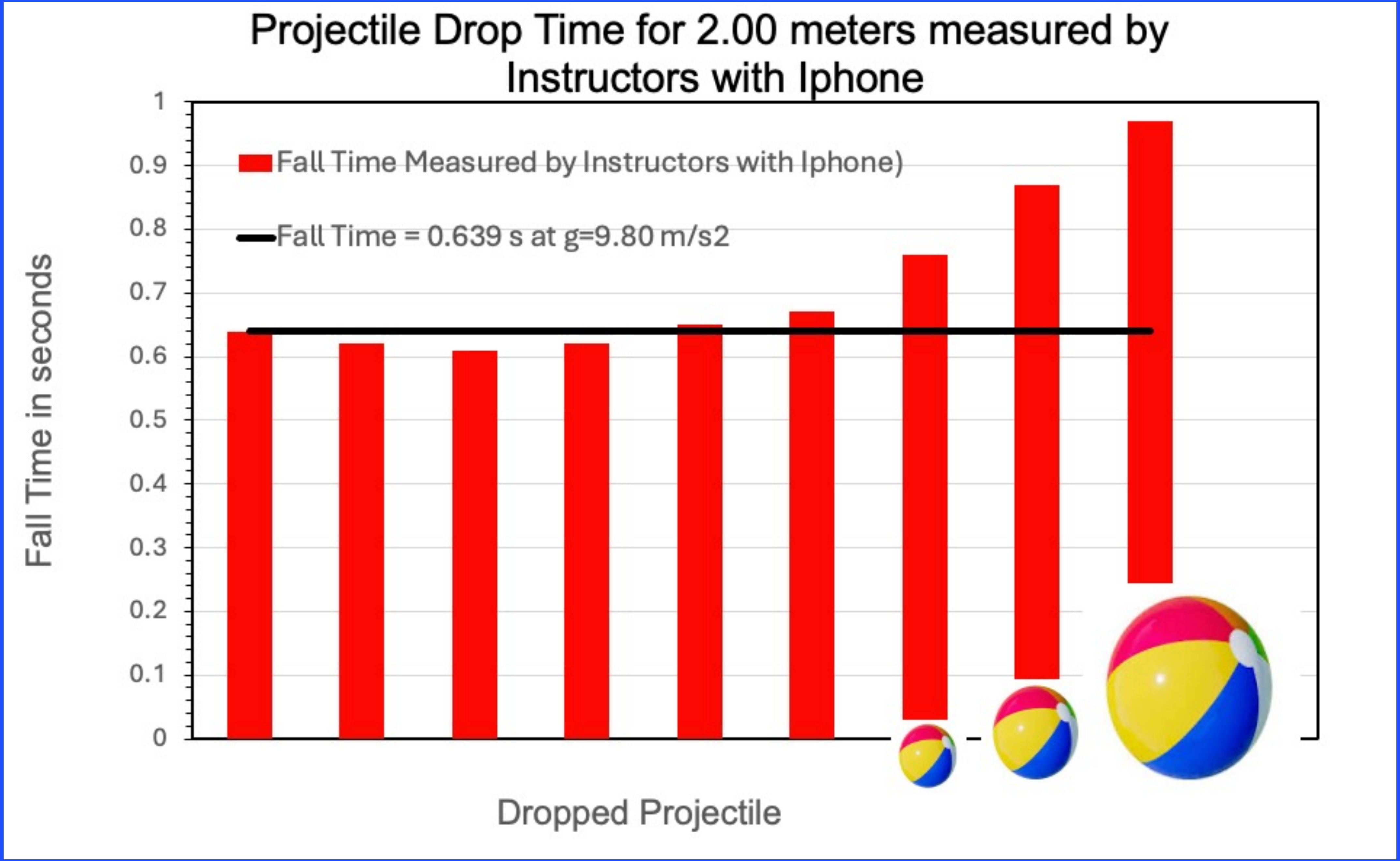
00:03:46

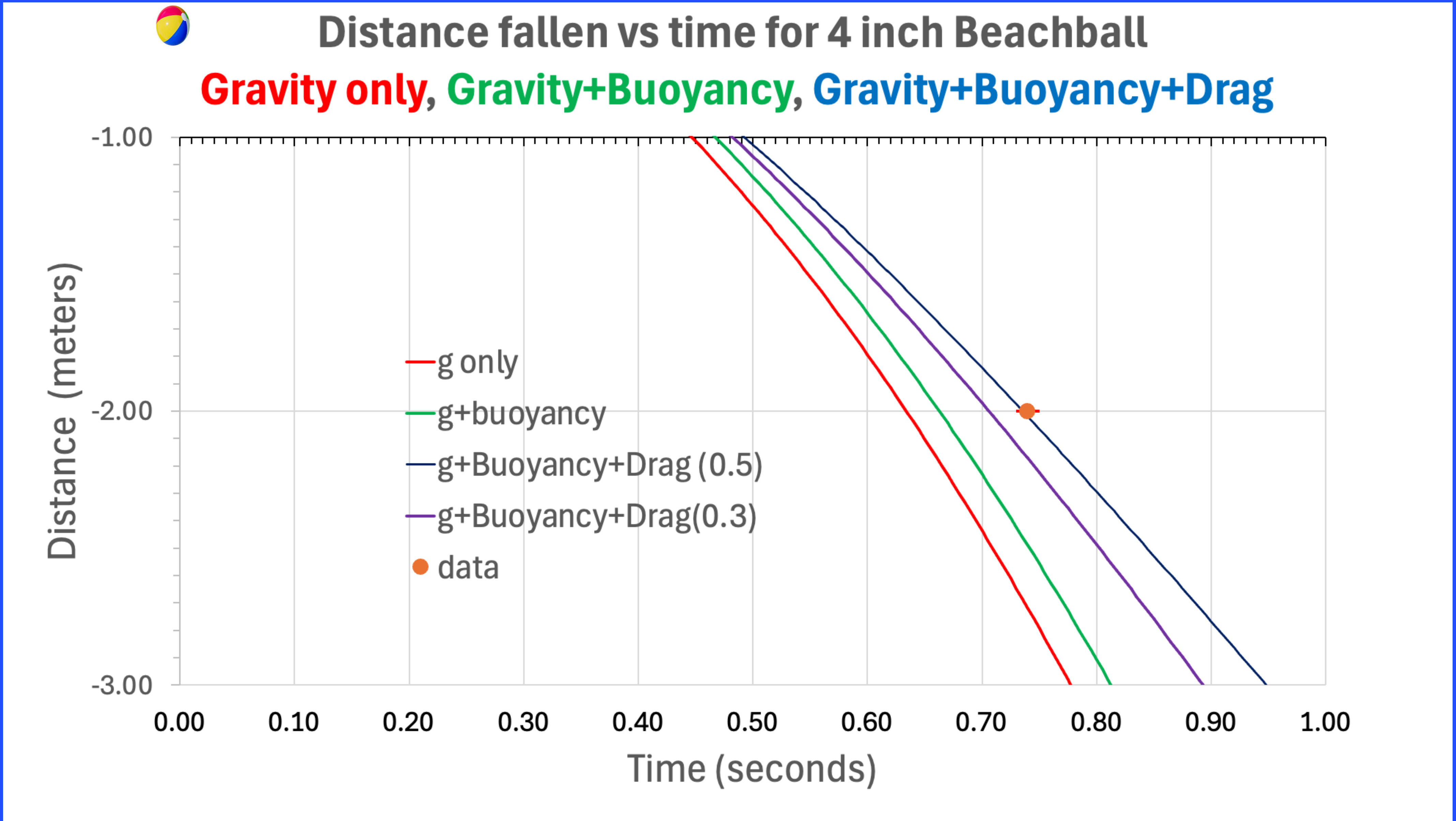

00:00:00:50
00:00:01:36
0.451s
00:03:62


00:10:56

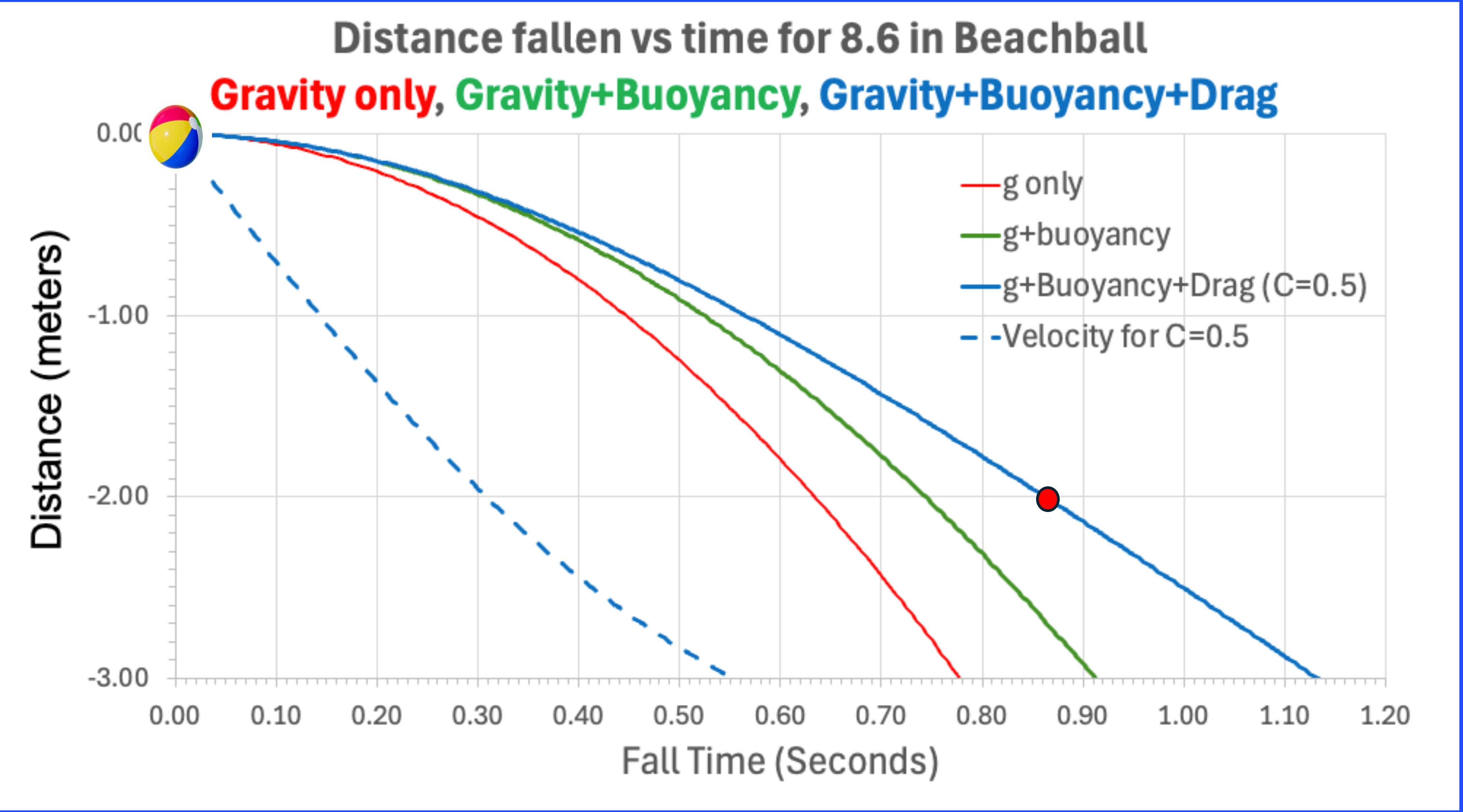

00:00:02:39
00:00:06:06
00:13:20
00:00:03:31
00:00:06:06
00:14:07


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

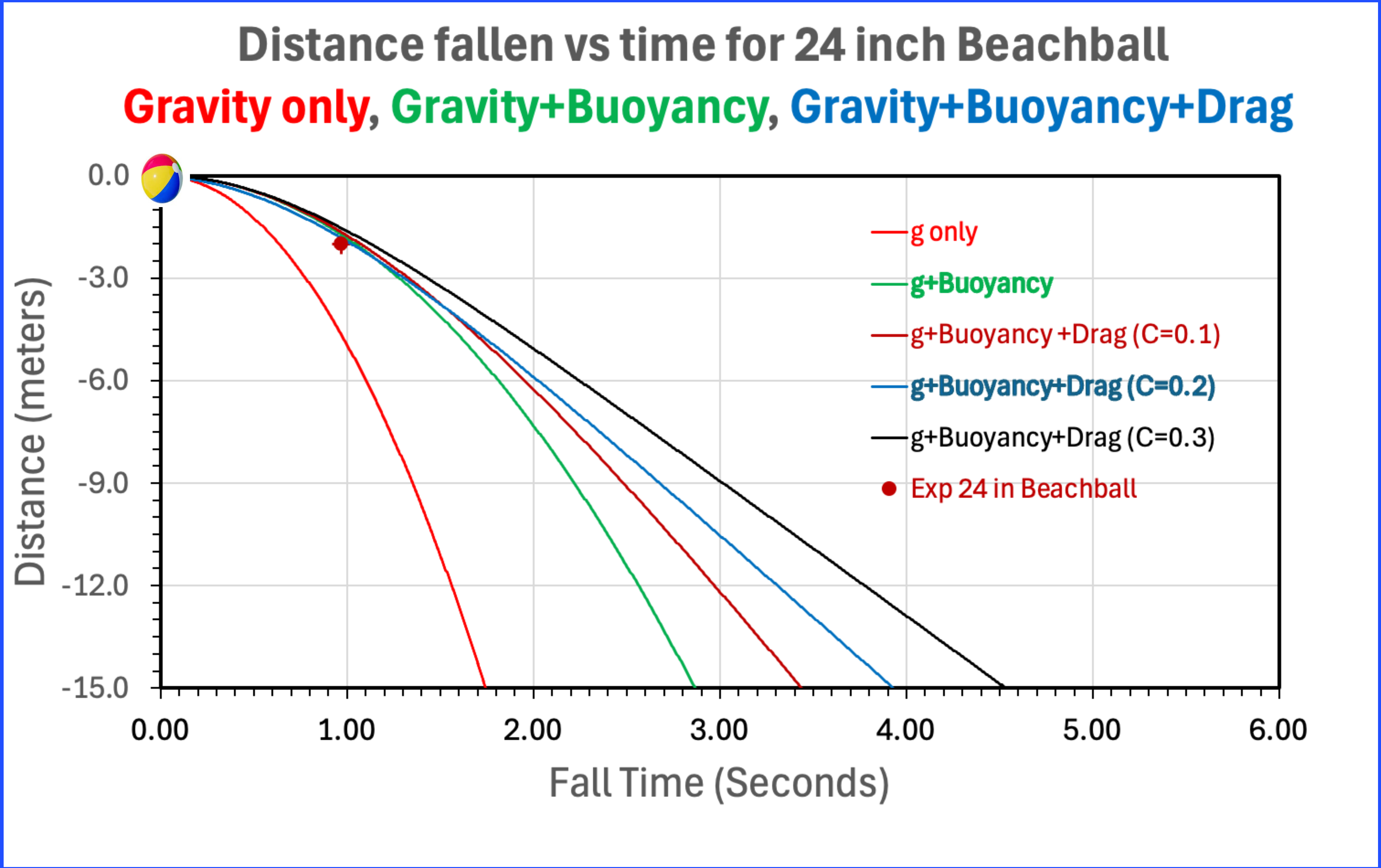

Projectile Drop Time for 2.00 meters measured by Instructors with Iphone
Fall Time Measured by Instructors with Iphone)
Fall Time = 0.639 s at g=9.80 m/s2
Fall Time in seconds
Dropped Projectile
1
0.9
0.8
0.7
0.6
0.5
0.4
0.3
0.2
0.1
0



Distance fallen vs time for 4 inch Beachball
Gravity only, Gravity+Buoyancy, Gravity+Buoyancy+Drag
-1.00
-2.00
-3.00
Distance (meters)
g only
g+buoyancy
g+Buoyancy+Drag (0.5)
g+Buoyancy+Drag(0.3)
data
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
g only
g+buoyancy
g+Buoyancy+Drag (C=0.5)
Velocity for C=0.5
Distance (meters)
0.00
-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
1.10
1.20
Fall Time (Seconds)


Distance fallen vs time for 24 inch Beachball
Gravity only, Gravity+Buoyancy, Gravity+Buoyancy+Drag
0.0
-3.0
-6.0
-9.0
-12.0
-15.0
Distance (meters)
0.00
1.00
2.00
3.00
4.00
5.00
6.00
Fall Time (Seconds)
g only
g+Buoyancy
g+Buoyancy +Drag (C=0.1)
g+Buoyancy+Drag (C=0.2)
g+Buoyancy+Drag (C=0.3)
Exp 24 in Beachball

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 classroom 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