Beach Ball Physics in Study Hall Solarium
(Magnus Effect)

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at Virginia Commonwealth University
Oct 11, 2025

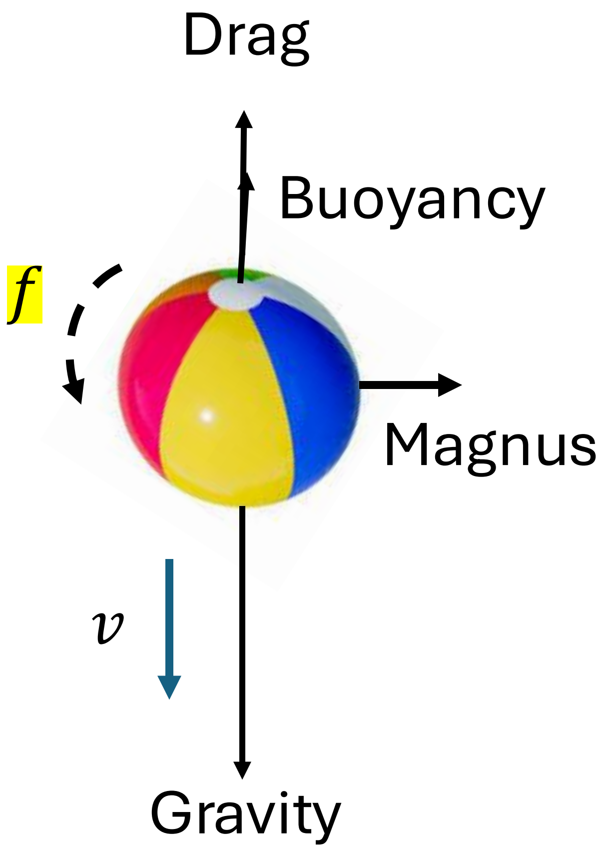
Various school projects on the Magnus Effect

- Homemade Devices to show off the Magnus Effect
- Glider cups wrapped with a rubber band
- Basketball flies off the dam

Let's look at a spinning beachball or object in free fall in air and see what forces are acting on it and consider how a Magnus for is produced.

The Forces acting on a spinning Beach Ball dropped from rest

$F_B = \rho \left(\frac{4}{3}\pi R^3\right) g$



$F_D = -CD(\rho A)(v^2)$

$A = \pi R^2$

ρ – density of air
R - radius of ball
v - velocity of ball
C_D – from experiment

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

f = frequency of rotation
C_L - from experiment

$F_g = mg$

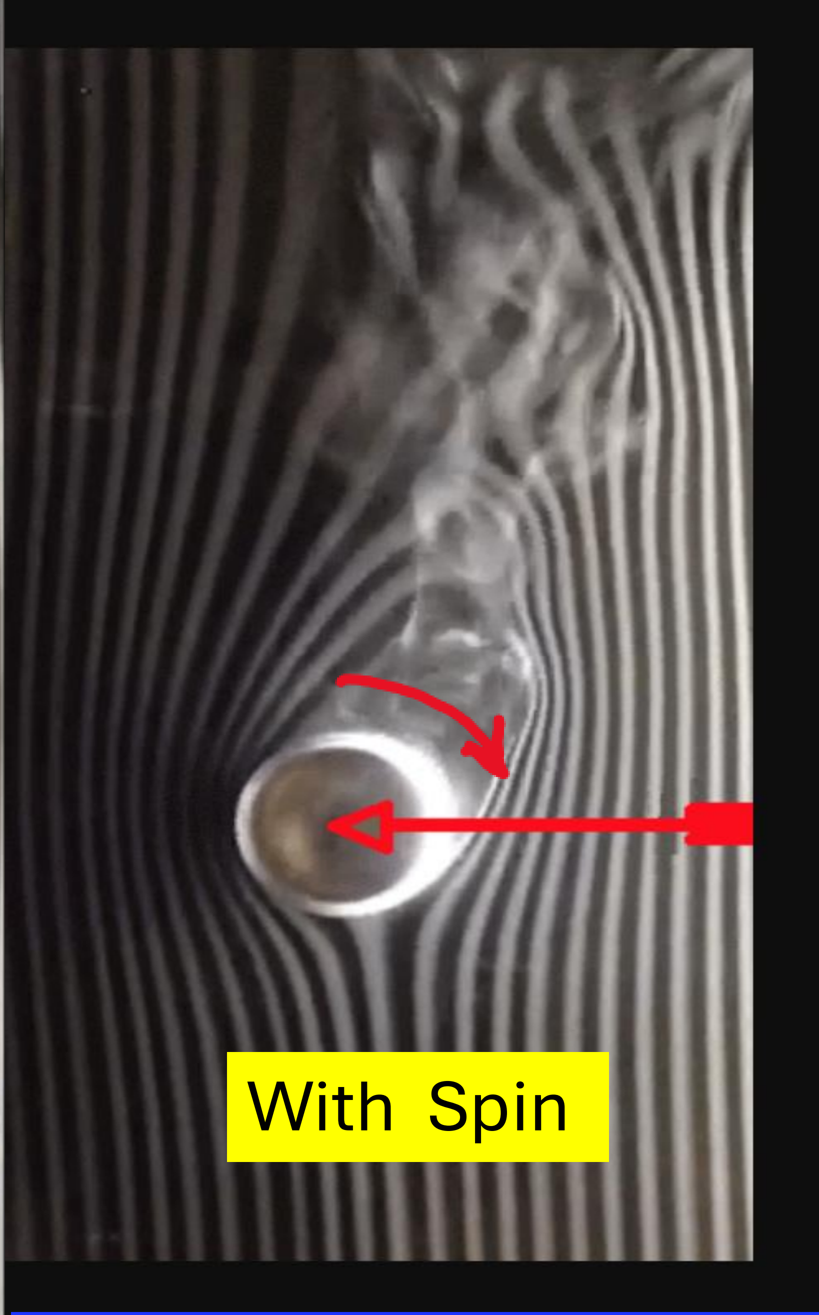
g- acceleration of gravity (9.80 m/s^2)

No spin

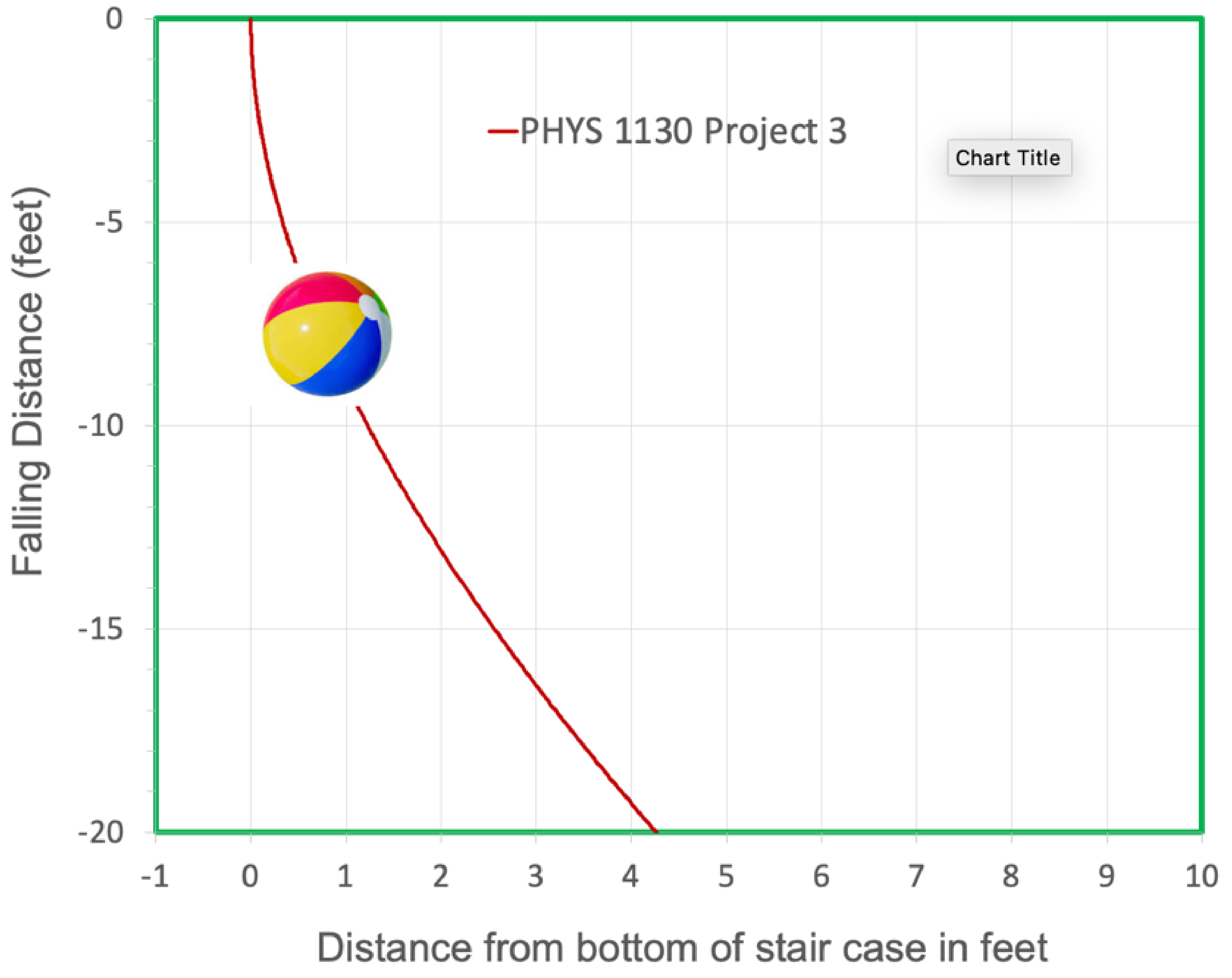
- Note the large region of pressure drag
- Note where the laminar flow line departs from the ball.

Spin

- Note Air flowing around the ball is dragged in the spin direction more than the other direction
- Air pressure is greater on the right hand side



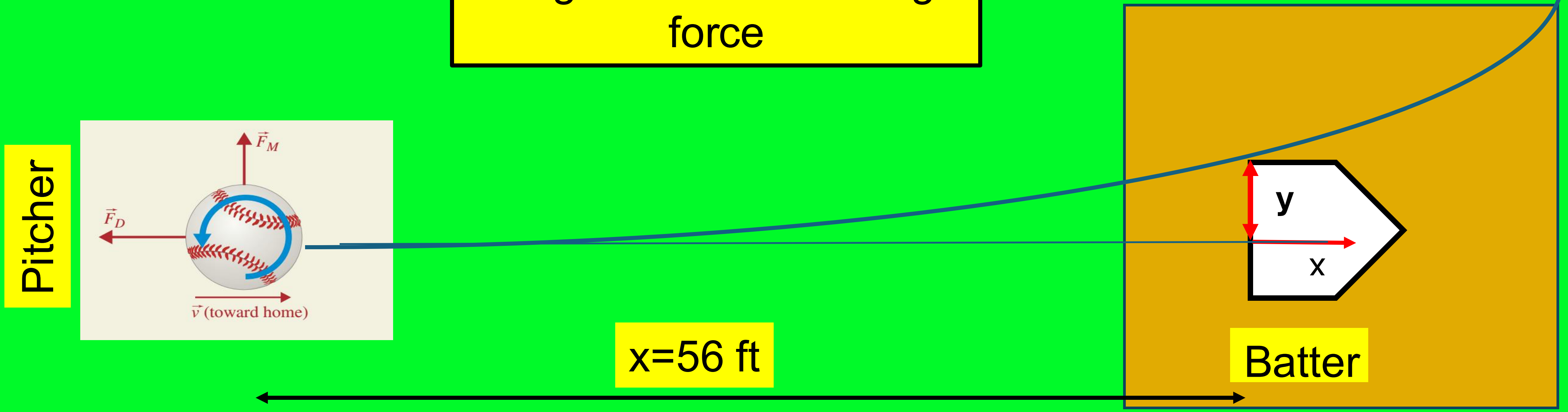
Large diameter spinning beachball dropped from balcony above staircase in the Physics buidling foyer



Looking down from above

Approximation Physics Neglect details of Drag force

Baseball Field



1. The deflection y is given by $y = \frac{1}{2} a_M t^2$ since the initial velocity $v_{0,y} = 0$
2. t=56 ft/ v_{avg}
3. v_{avg}=0.95 v where v is the pitcher's release velocity and 10% is the loss in speed due to drag at 100 mph
4. The acceleration in the y direction is given by $a_M = \frac{|\vec{F}_M|}{m}$
5. And $|\vec{F}_M| = \pi^2 C_L \rho_{air} R^3 v_{avg} f$
6. All the other quantities in 5 are known and f the rotational frequency must also be given.
7. You can assume the lift coefficient or Magnus coefficient is 1 or use some model or exp to determine it.

Project 3 Determine the Lift Coeficient C_L

Students will mount their iphone or camera on a tripod on the stairwell not shown in the picture.

Students work in pairs and one student will release the ball with backspin and the other student will operate the iphone camera.

After recording the dropped ball students can transfer the video to imovie and replay it to determine the fall time accurately and measure x and y distances using the white labeled grid and also the tiles on the floor for checks and balances.

Project 3 Determine the Lift Coefficient C_L

The lift coefficient can be written as

$$C_L = \frac{m\, a_x}{\pi^2\, \rho_{air}\ R^3\, v_{avg}\, f}$$

1. Neglect the drag force since it appears to be small for our low velocities. The total mass m, ρ_{air} and R^3 are easily obtained.

   The mass is the mass of the skin plus the mass of the air.

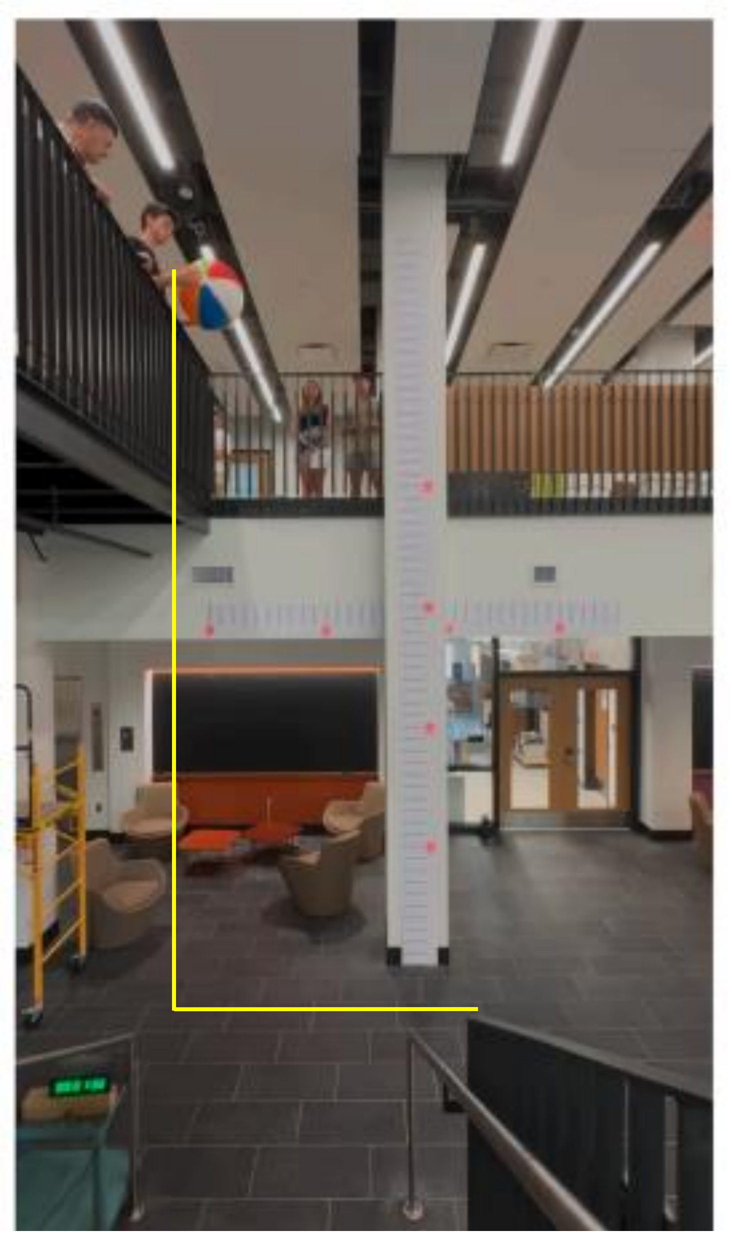
2. a_x is determine $a_x = 2\,x/t^2$ assuming a_x is approximately constant. Measuring the lateral displacement x from the grid on the video replay and obtain t from the digital clock and iphone camera which should agree. This is a good check.

Continued

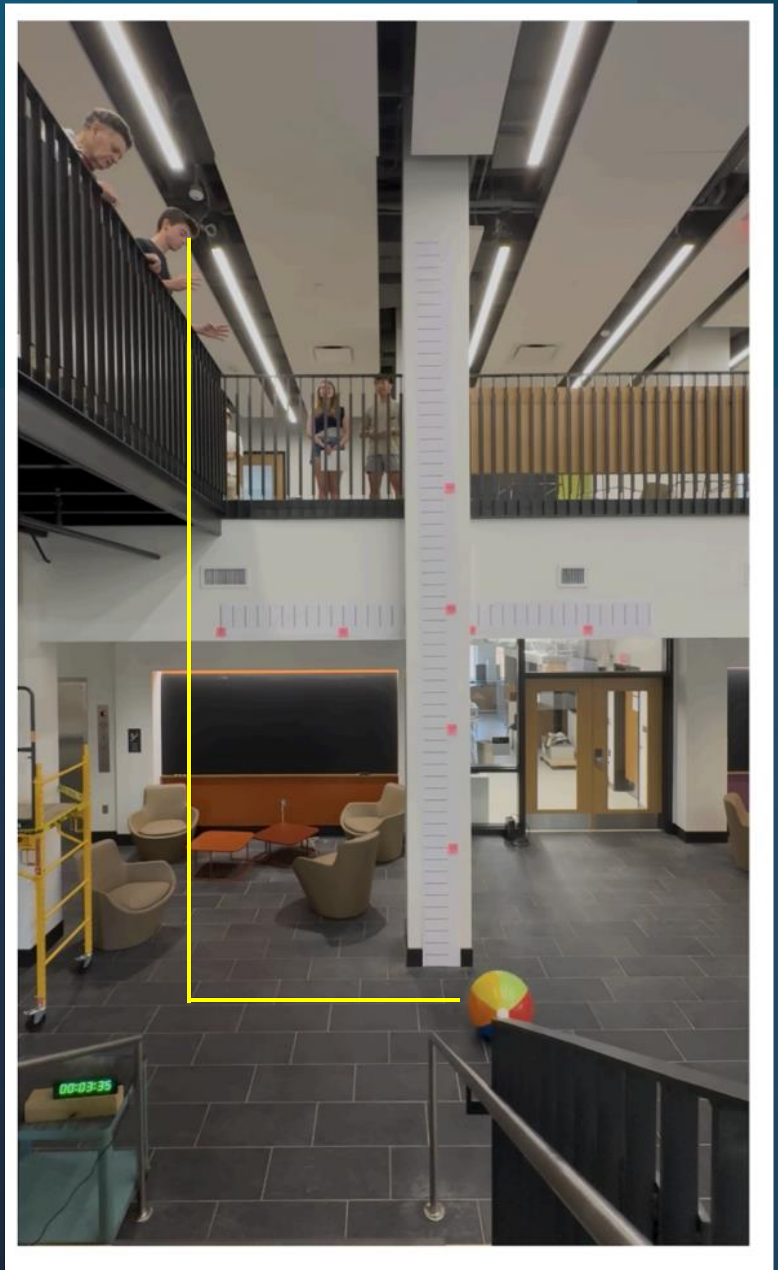
3. v_{avg} is determined from $v_{avg} = \frac{1}{2}\sqrt{2a_y y}$ where y is the distance the ball is dropped.

4. The acceleration a_y is determined from $a_y = 2y/t^2$ and should agree with the expected effect due to buoyancy $g_{eff} = (1 - \rho_{air} V/m)g$ where m is the mass of the balloon skin plus mass of the air inside the ball.

5. f the rotational frequency is measured using the frame rate and slowing down the video so you count the rotations that the ball is spinning.



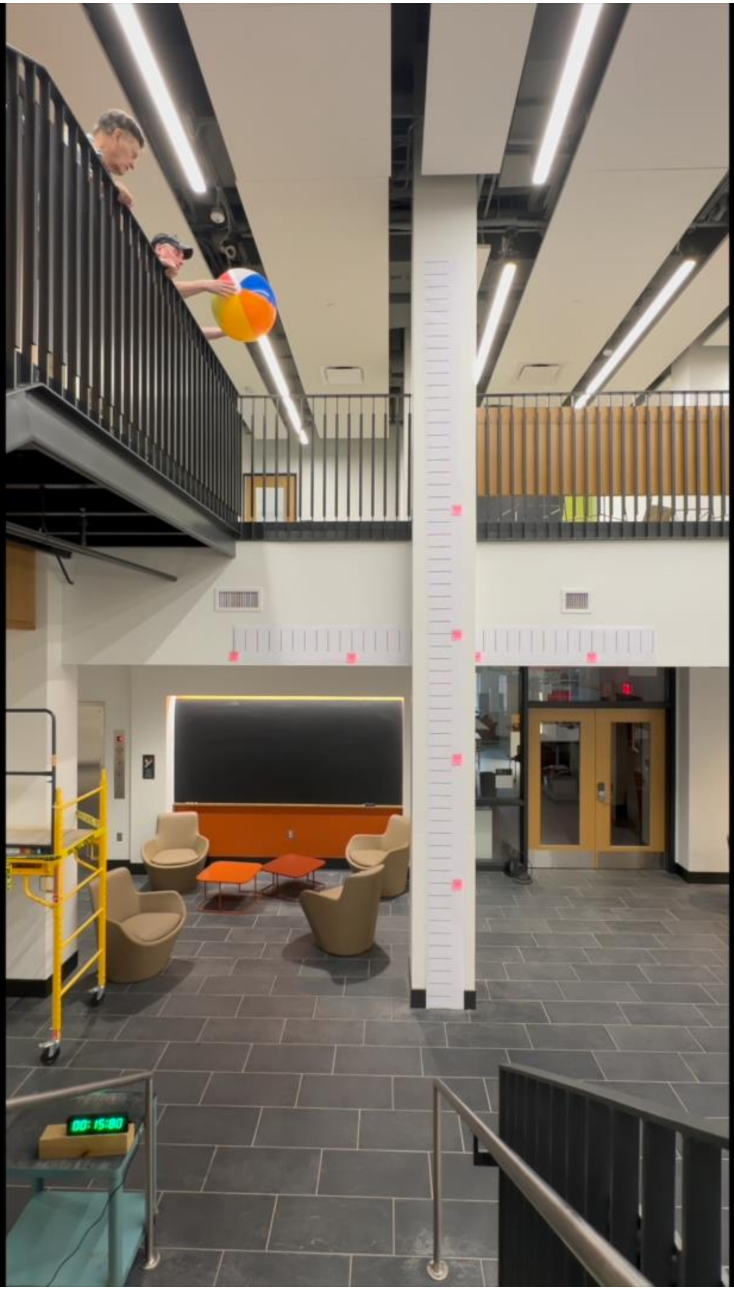
Student is putting backspin on the ball as he releases it 5 m above the floor.



As the ball falls the Magnus force displaces the ball 2-3 m from its initial position

A Couple of Students Practicing

- IMG_5080.mov
- IMG_5075.mov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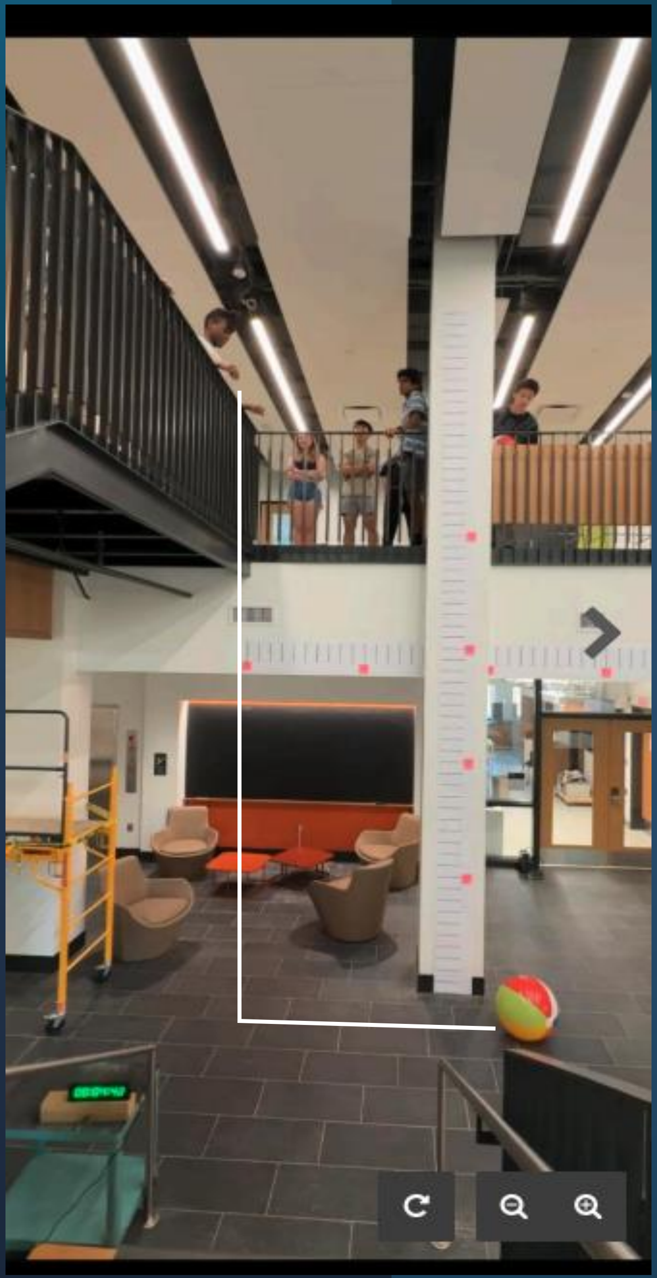

Results for Determining Lift Coefficient C_L from dropping a 17 in Spinning ball

Students	C_L (Magnus Coefficient).	C_L Corrected value for mass	C_L Nominal Value
• A & B	0.080	0.128	0.5
• C & D	0.154	0.243	0.5
• E	0.0586	0.088	0.5
• F & G	0.145	0.229	0.5
• H & I	0.214	0.338	0.5

- Most students used the mass by weighing the beach ball uncorrected for buoyancy.

The Forces acting on a spinning Beach Ball dropped from rest

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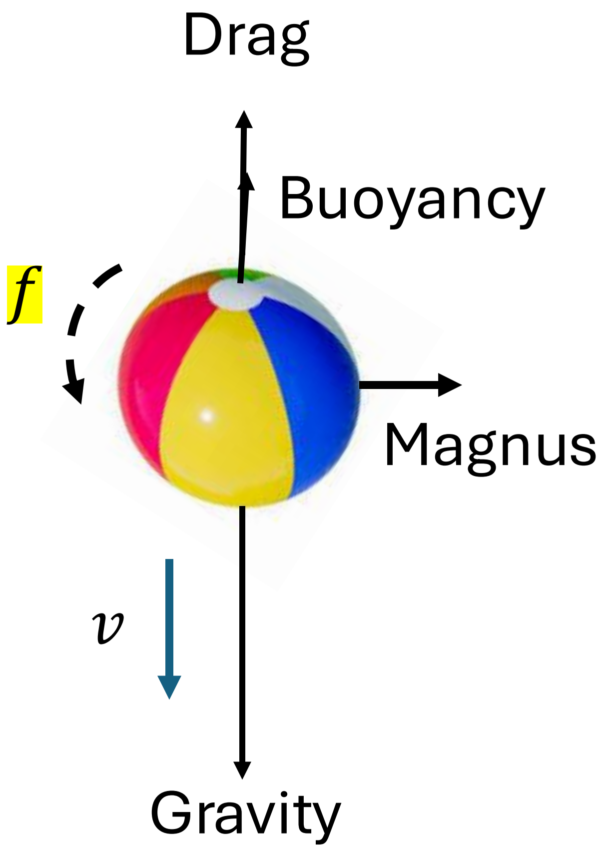

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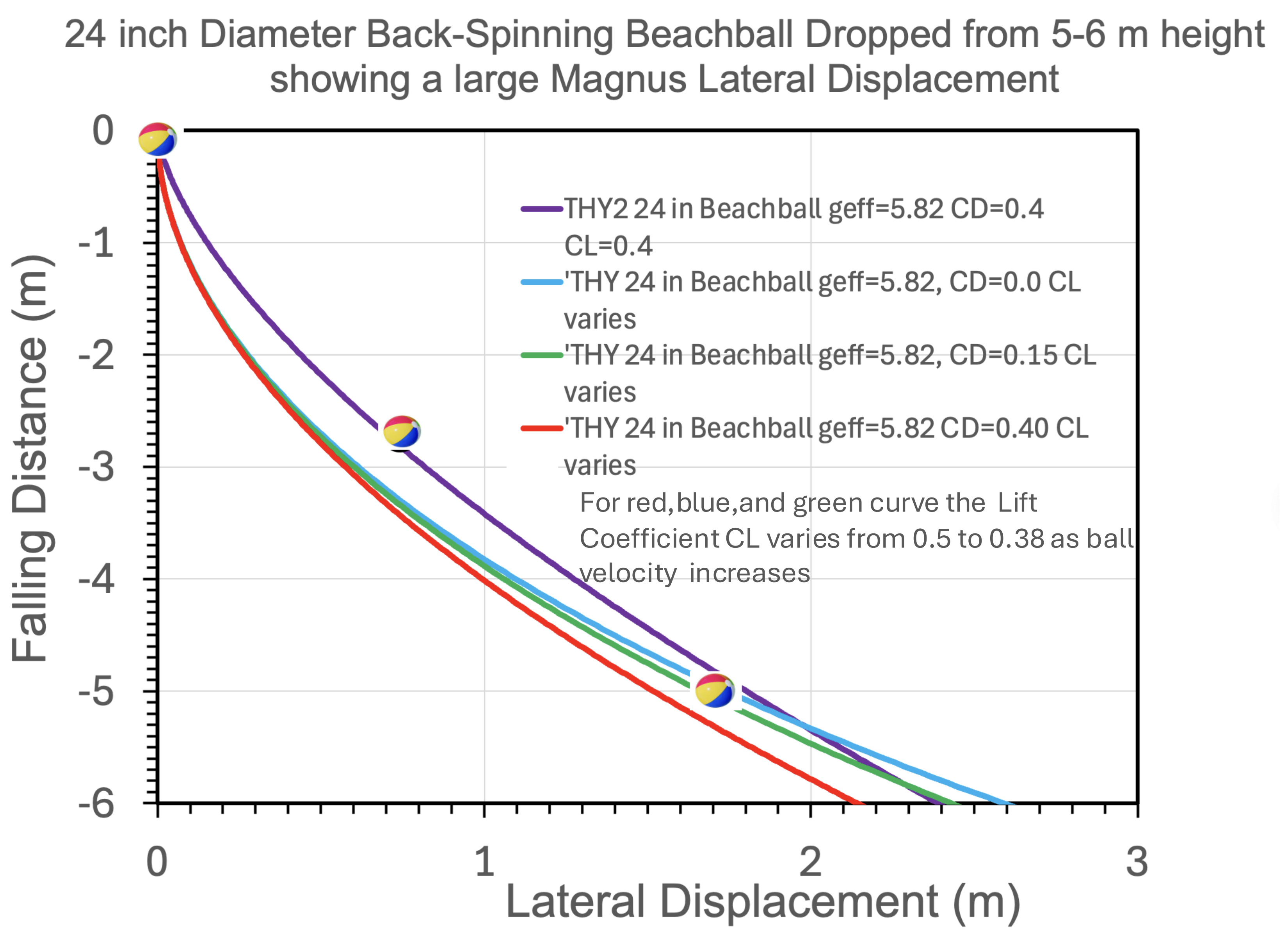
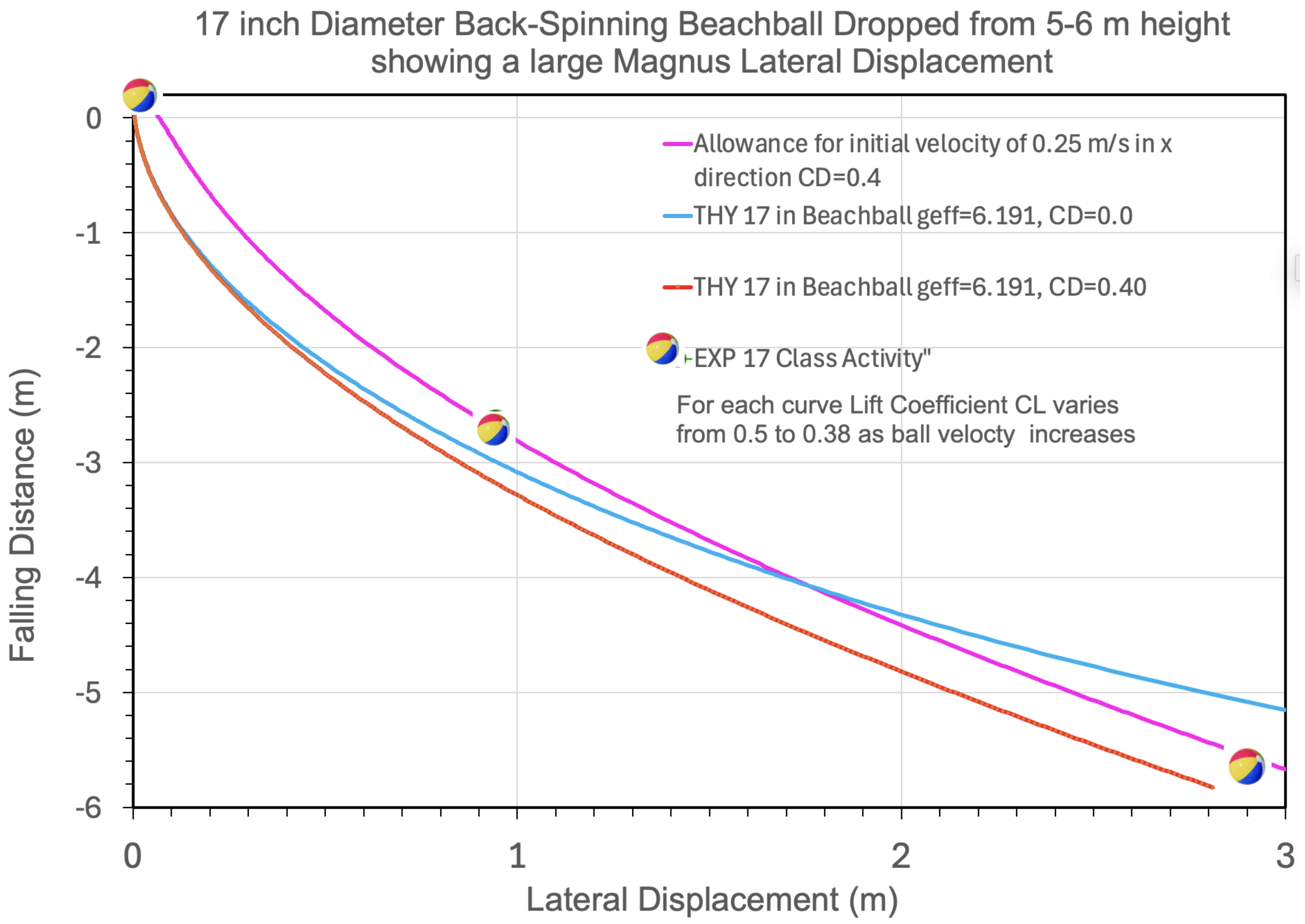
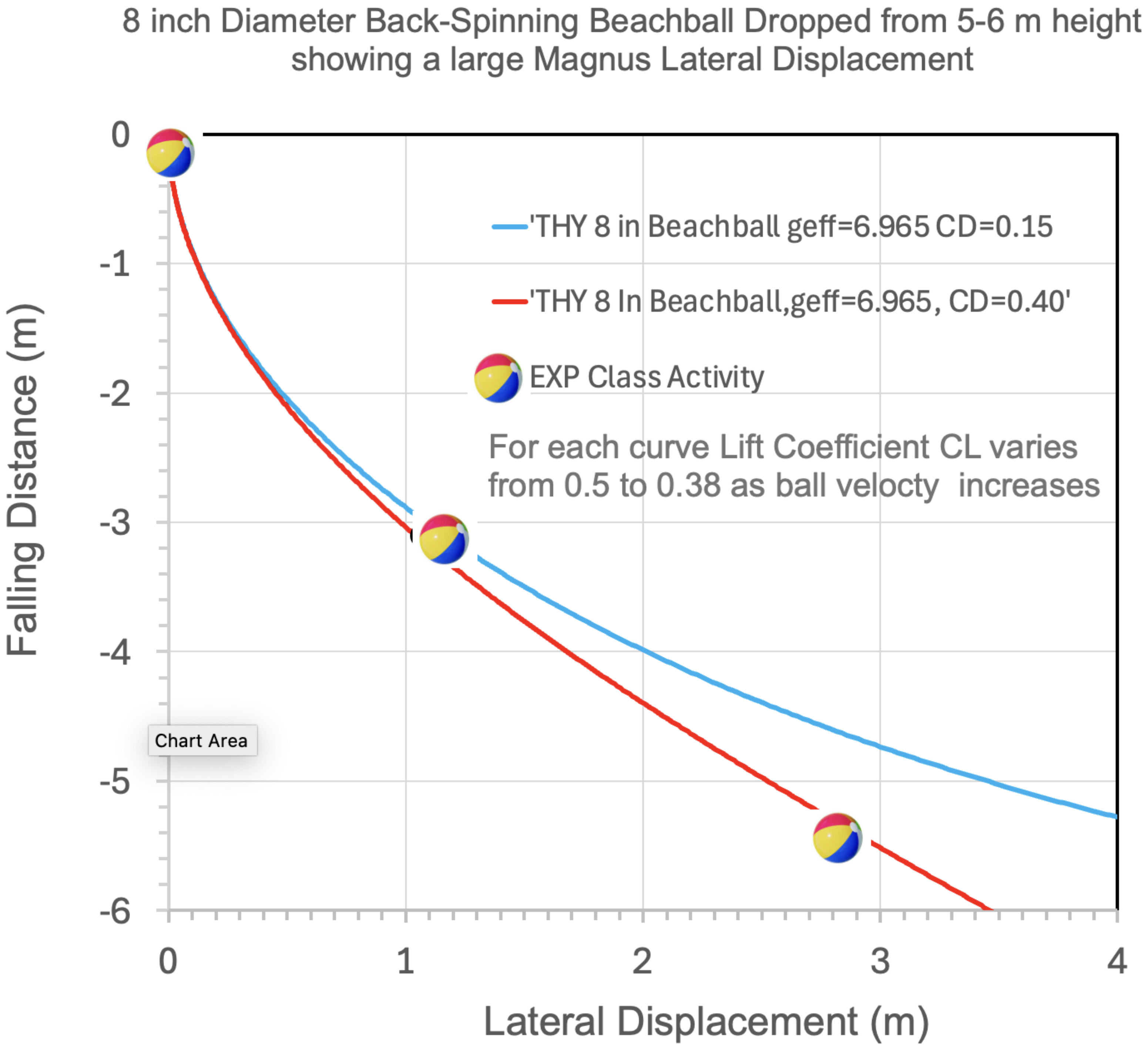
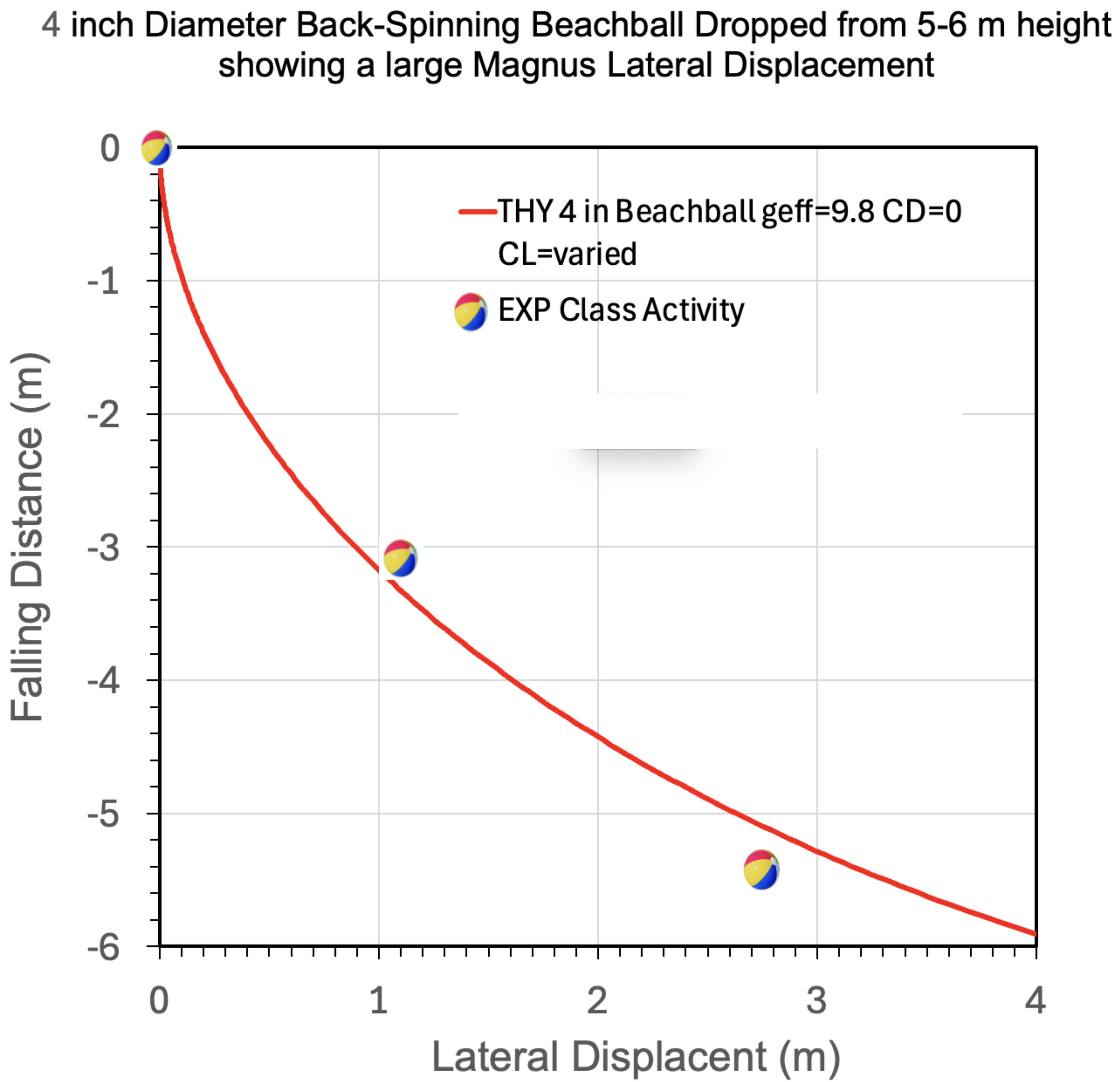

24 inch Diameter Back-Spinning Beachball Dropped from 5-6 m height
showing a large Magnus Lateral Displacement
THY2 24 in Beachball geff=5.82 CD=0.4 CL=0.4
'THY 24 in Beachball geff=5.82, CD=0.0 CL varies
'THY 24 in Beachball geff=5.82, CD=0.15 CL varies
'THY 24 in Beachball geff=5.82 CD=0.40 CL varies
For red, blue, and green curve the Lift Coefficient CL varies from 0.5 to 0.38 as ball velocity increases
Falling Distance (m)
Lateral Displacement (m)
0
-1
-2
-3
-4
-5
-6
0
1
2
3


17 inch Diameter Back-Spinning Beachball Dropped from 5-6 m height
showing a large Magnus Lateral Displacement
Allowance for initial velocity of 0.25 m/s in x direction CD=0.4
THY 17 in Beachball geff=6.191, CD=0.0
THY 17 in Beachball geff=6.191, CD=0.40
EXP 17 Class Activity"
For each curve Lift Coefficient CL varies from 0.5 to 0.38 as ball velocty increases
Falling Distance (m)
Lateral Displacement (m)
0
-1
-2
-3
-4
-5
-6
0
1
2
3


8 inch Diameter Back-Spinning Beachball Dropped from 5-6 m height
showing a large Magnus Lateral Displacement
'THY 8 in Beachball geff=6.965 CD=0.15
'THY 8 In Beachball,geff=6.965, CD=0.40'
EXP Class Activity
For each curve Lift Coefficient CL varies
from 0.5 to 0.38 as ball velocty increases
Chart Area
Falling Distance (m)
Lateral Displacement (m)
0
-1
-2
-3
-4
-5
-6
0
1
2
3
4


4 inch Diameter Back-Spinning Beachball Dropped from 5-6 m height
showing a large Magnus Lateral Displacement
THY 4 in Beachball geff=9.8 CD=0 CL=varied
EXP Class Activity
Falling Distance (m)
Lateral Displacent (m)
0
-1
-2
-3
-4
-5
-6
0
1
2
3
4

Conclusions

1. Can't do much better with iphone cameras
2. Pasco with its ultrasound sensor does not work well beyond 4 meters
3. Really need a better tool to measure position and time with higher accuracy
4. Also need longer drop times to get better separation between curves.

   Therefore, need something more accurate than iphone cameras.
5. Our physics of Sports Class has 3 projects during the summer

   which seems to help their enthusiasm for the subject if not there already.