The Physics behind the Law of Football

In this Activity you will carry out two Experiences; *one related to the Magnus force (F_M) and the other related to the restitution coefficient (ε).*

A) PREDICTING THE DIRECTION OF THE MAGNUS FORCE: You will be given a set of balls and a "curve ball flinger", this device has been custom-made to help throw balls that spin when they are thrown.

Materials: "Curve ball Flinger", set of small balls, one cell phone per group, scale, measuring tape.

1. **Analyze the "curve ball flinger" device and predict:**

Hand that will be employed	**Seen from the top: how will the ball spin ?** (clockwise or counterclockwise)	**Make a schematic drawing of the top view of the ball:** the spin, the forces and direction.	**Predict which way will the Magnus Force curve the ball** (to the right or to the left)
Right hand			
Left hand			

2. **Use the "curve ball flinger"** to throw the ball and observe, it can be useful to record a **video** from behind the person throwing the ball with a **"SLO MO"** to better analyze the situation later.

Throw	**HAND (Right or left)**	**Ball**	**The ball curved to the Right or left?**	**Observations (details about the ball, the thrower, forces… that you estimate relevant to the trajectory of the ball)**
1				
2				
3				
4				
5				

3. **Analyze the results:** Did the ball curve as you predicted? When thrown with the same hand, do all the balls behave in the same way? Why or why not? Have you observed any other factors that affect the magnitude of the Magnus force?

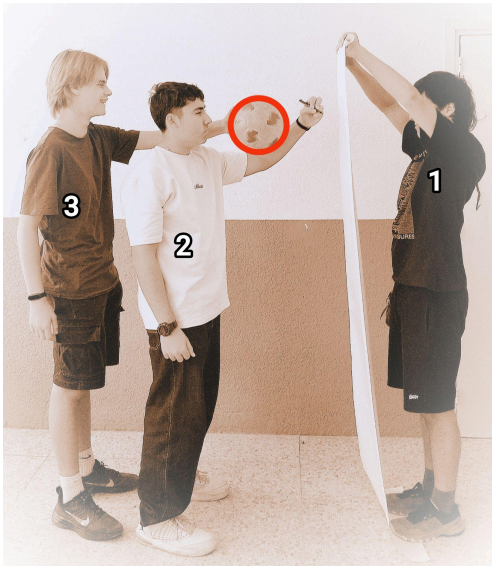
B) EFFECT OF MATERIALS AND PRESSURE ON THE RESTITUTION COEFFICIENT OF A FOOTBALL: you will be given a rolled paper that you will use to mark the height of the ball before and after bouncing.

Materials: 2,4 m long rolled wall paper, colored pencils, set of footballs, measuring tape, scale, manometer, string, football pump.

1. **Analyze and predict:** set the pressure to _____ psi, fill the non shaded cells of the following table by measuring and predicting.

Ball	What material is made of? Does it have seams?	Measure the weight, the circumference and indicate the exact pressure	Predict which will have the HIGHEST and LOWEST restitution coefficient	h_1 (m)	h_3 (m)	Restitution Coefficient
A		Weight: Circumference: Pressure:				
B		Weight: Circumference: Pressure:				
C		Weight: Circumference: Pressure:				

2. **Procedure to measure h_1 and h_3 and calculate the restitution coefficient (requires three people):**



a. **Set up the measuring surface:** Person 1 holds the 2.4 m long rolled wallpaper vertically and perpendicular to the floor. This can be done by securing the bottom with the feet and holding the top with the hands, or by attaching it to the wall.

b. **Position and initial marking:** Person 2 stands in front of the wallpaper with a marker and is responsible for marking the initial and final heights of the ball. Person 3 stands behind Person 2 holding the ball in front of Person 2. Person 2 marks on the wall paper the **initial height** of the top of the ball (h_1) **before it is dropped**.

c. **Drop the ball:** Person 3 releases the ball so it falls freely, allowing Person 2 to mark the **maximum height after the bounce** (h_3). *To distinguish between different trials, write the **test number** next to each mark.*

$$\frac{Ep_3}{Ep_1} = \frac{Ec_r}{Ec_i}$$

$$\frac{m \cdot g \cdot h_3}{m \cdot g \cdot h_1} = \frac{1/2 \cdot m \cdot v_r^2}{1/2 \cdot m \cdot v_i^2}$$

$$\frac{h_1}{h_3} = \frac{v_r^2}{v_i^2}$$

$$\sqrt{\frac{h_1}{h_3}} = \frac{v_r}{v_i} = \varepsilon$$

d. **Measure h_1 and h_3** wiith the measuring tape, and fill the information in the table above.

e. **Calculate the restitution coefficient:** The restitution coefficient (ε) can be measured directly by determining the velocity of the ball just **before** (v_i) and just **after** (v_r) it hits the ground. Alternatively, it can be **calculated from h_1 and h_3.** Using the principle of conservation of energy we can follow the physical and mathematical reasoning behind this relationship is outlined on the right.

3. **Repeat step 2 but changing the pressure of one of the balls.** Record the data filling the most shaded cells in the table.

$$\frac{Ep_3}{Ep_1} = \frac{Ec_r}{Ec_i}$$

$$\frac{m \cdot g \cdot h_3}{m \cdot g \cdot h_1} = \frac{1/2 \cdot m \cdot v_r^2}{1/2 \cdot m \cdot v_i^2}$$

$$\frac{h_1}{h_3} = \frac{v_r^2}{v_i^2}$$

$$\sqrt{\frac{h_1}{h_3}} = \frac{v_r}{v_i} = \varepsilon$$