



ISTAGE 3

TEACHING UNIT „UNDER PRESSURE“

ACTIVITIES AND EXPERIMENTS WITH THE AIR PRESSURE INSIDE THE BALL

Corina TOMA

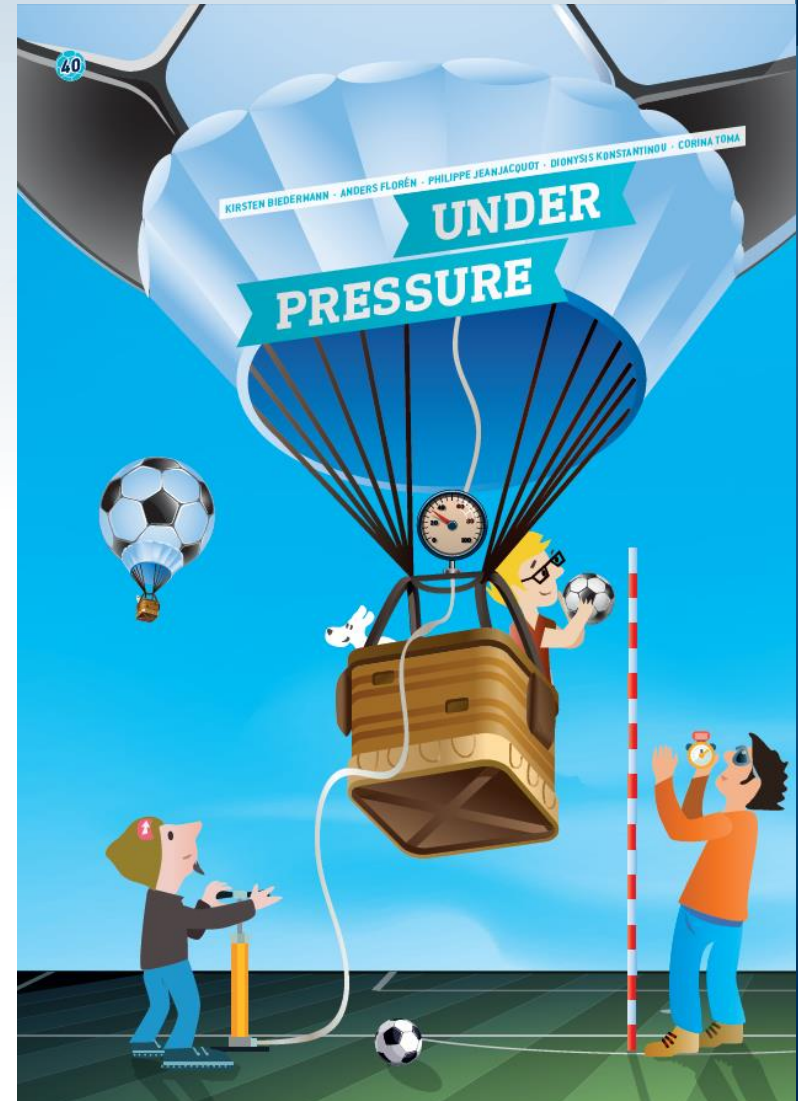
Philippe JEANJACQUOT

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★ PRESSURE

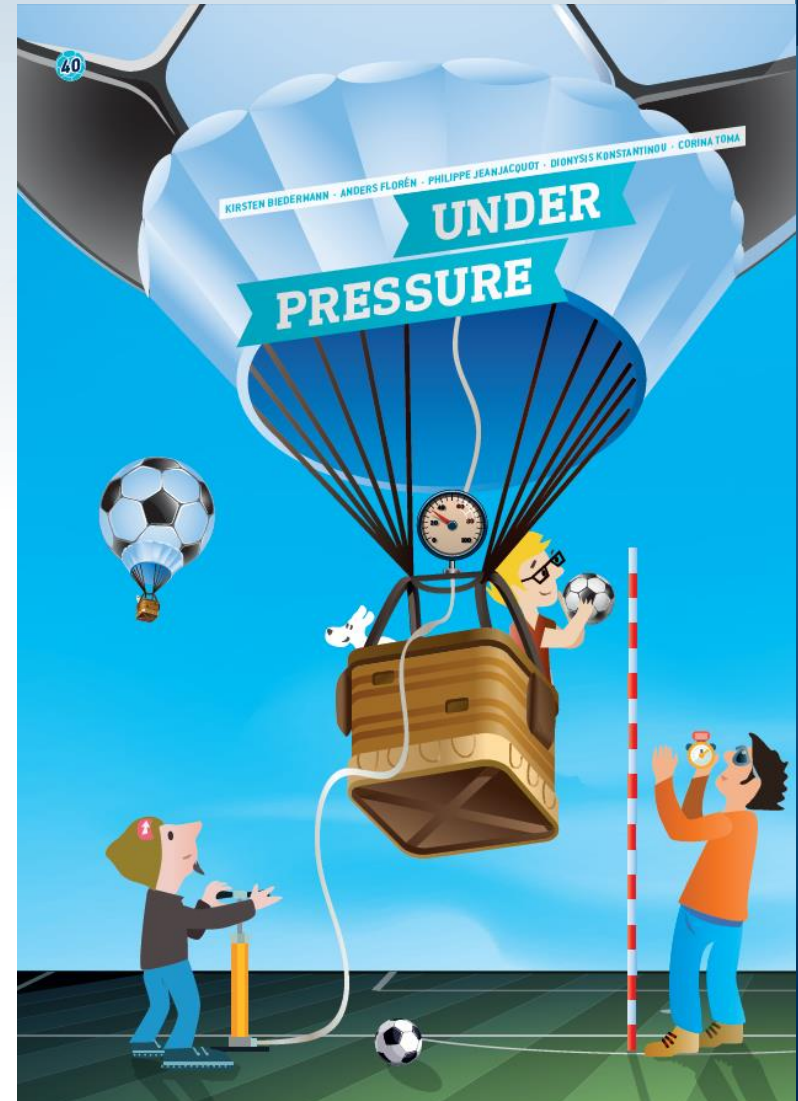
★ BOUNCE



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★ PRESSURE




An inventive way to study the properties of the air across the football







PRESSURE: WHAT WE ARE GOING TO DO



WE ARE GOING TO MEASURE:

-  The pressure inside the ball
-  The mass of the ball
-  The volume of the ball

WE ARE GOING TO FIGURE OUT:

-  That air has a mass.
-  The link between the pressure and the mass of the air.
-  The density of the air.
-  The ideal gas law and the mass of one mole of air.

PRESSURE: FIT TO EVERY LEVEL



PRIMARY SCHOOL:



The air has a mass.

MIDDLE SCHOOL:



The link between the pressure and the mass of the air.



Density of the air.

HIGH SCHOOL:

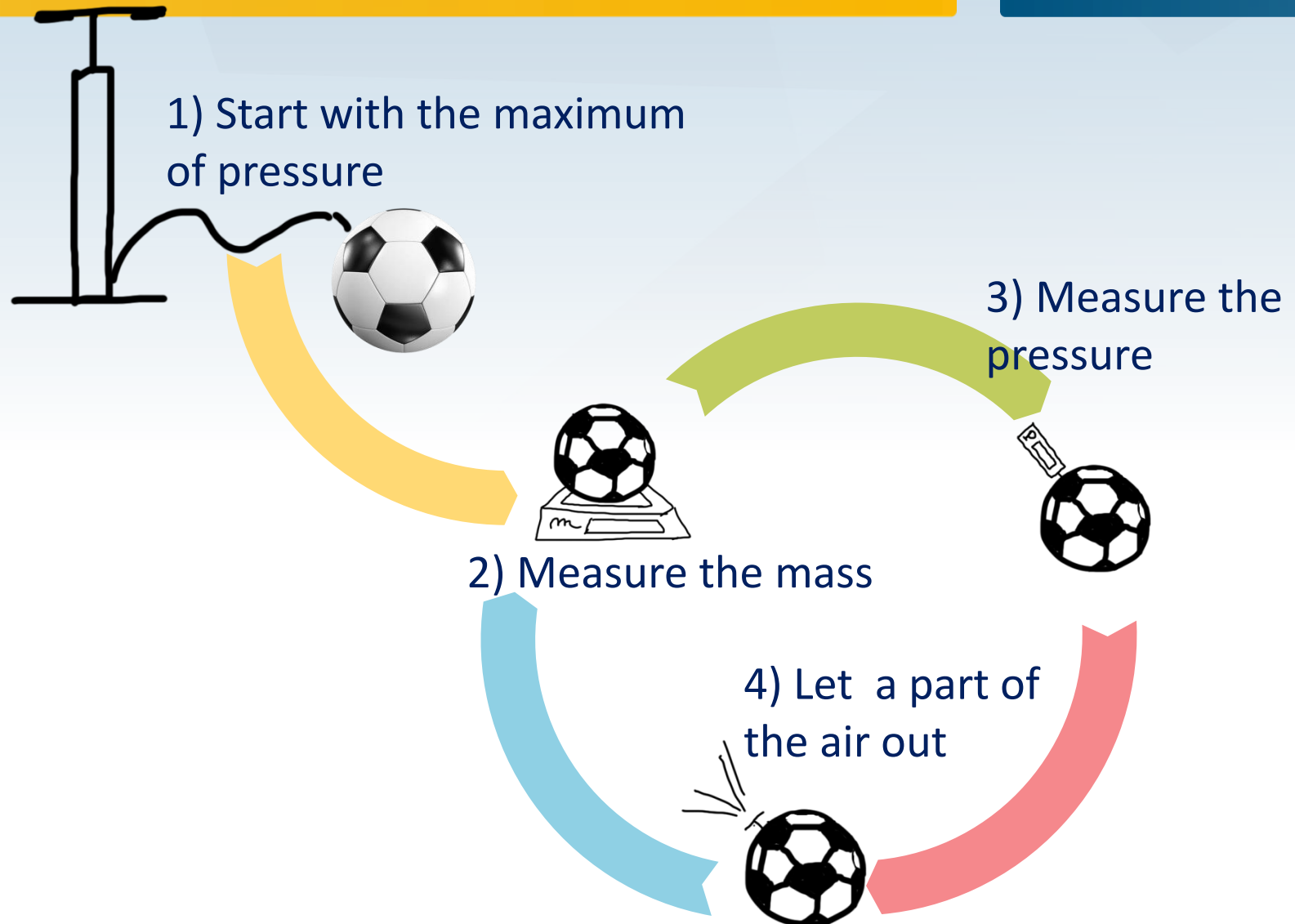


The ideal gas law and the mass of one mole of air.



Show the effect of the buoyancy of the air.

PRESSURE: PROCEDURE



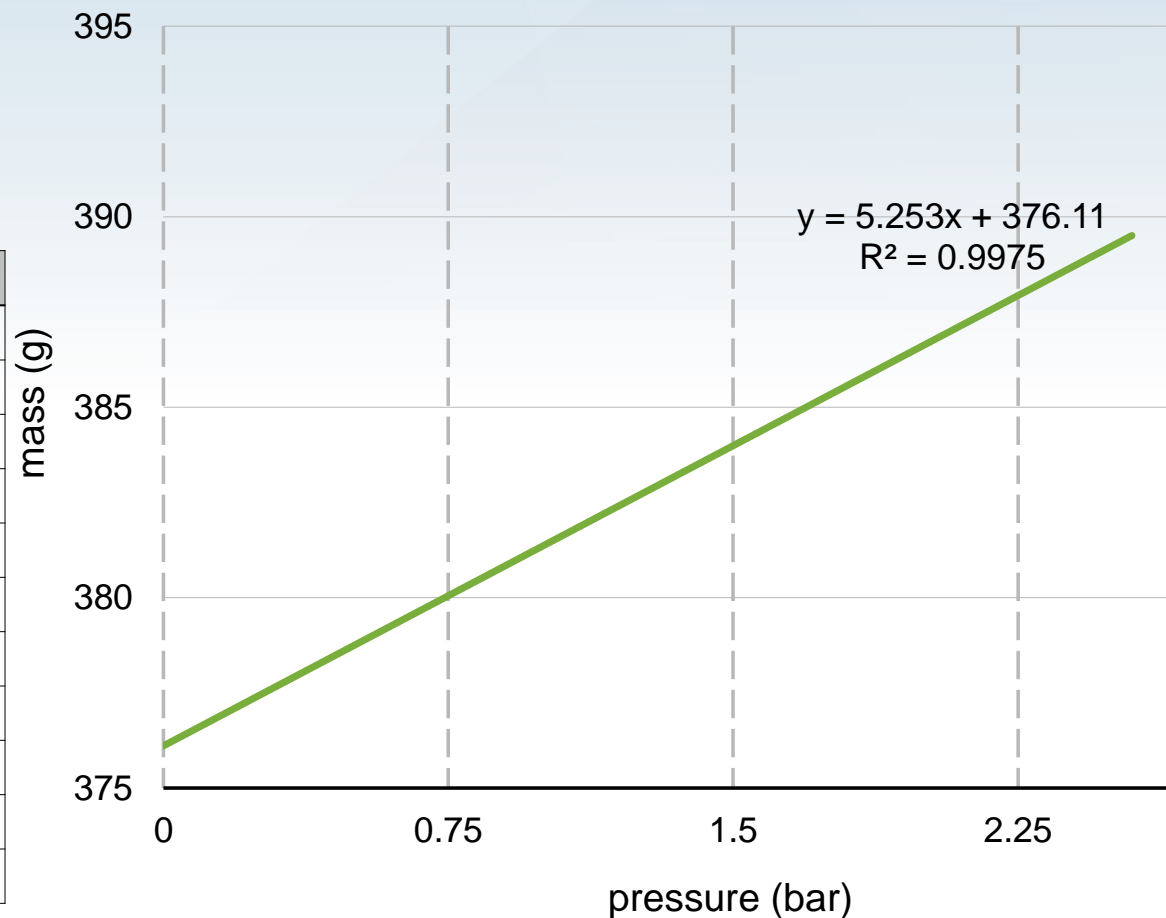
PRESSURE: MEASURES

✚ mass vs pressure — BEST FIT

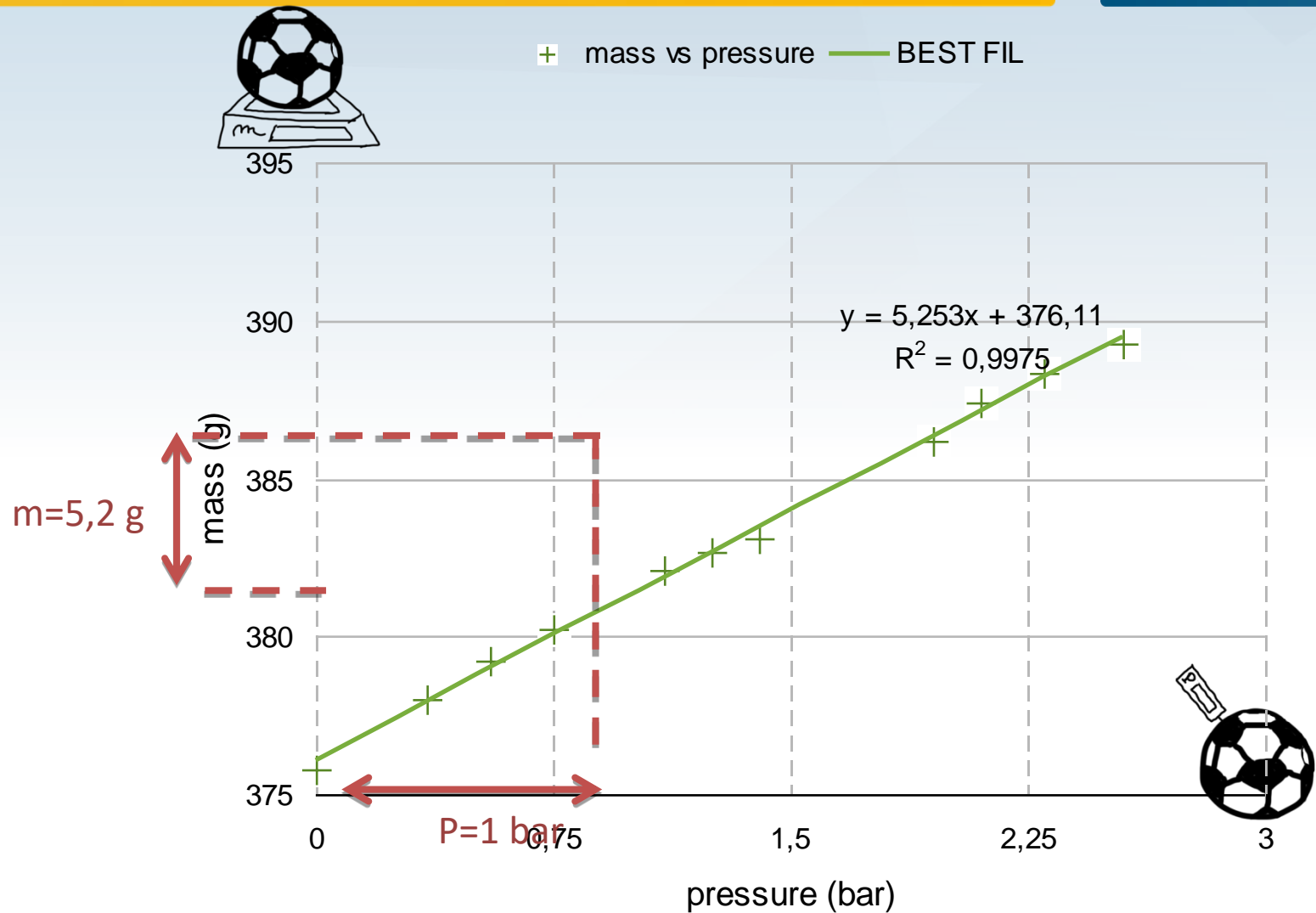


MASS vs. PRESSURE

PRESSURE (bar)	MASS (g)
2.55	389.3
2.3	388.3
2.1	387.4
1.95	386.2
1.40	384.1
1.25	382.7
1.10	382.1
0.75	380.2
0.55	379.2
0.35	378
0	375.8



PRESSURE: MASS OF AIR



MASS OF AIR INSIDE THE BALL

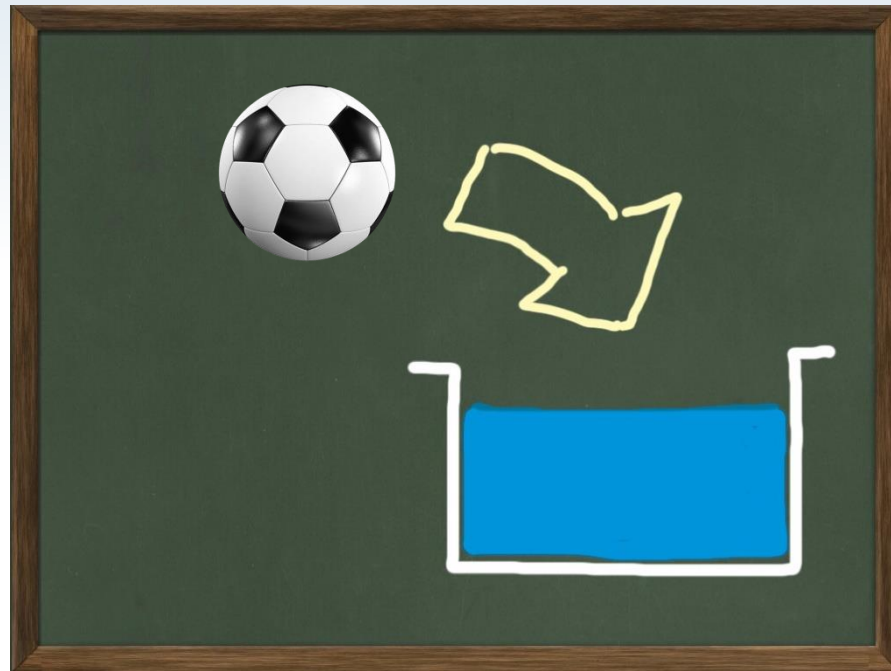


Mass of air inside the ball
 $m = 5.2 \text{ g}$ for $p = 1 \text{ bar}$

VOLUME OF THE BALL



VOLUME OF THE BALL



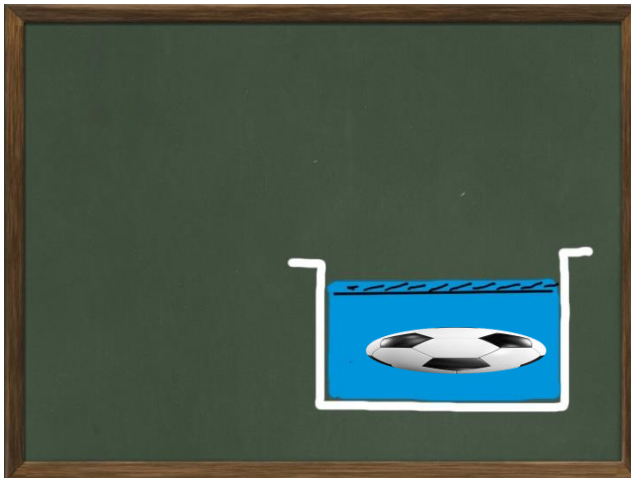
VOLUME OF THE BALL

$h(\text{full}) = 5.6 \text{ cm}$



VOLUME OF THE BALL

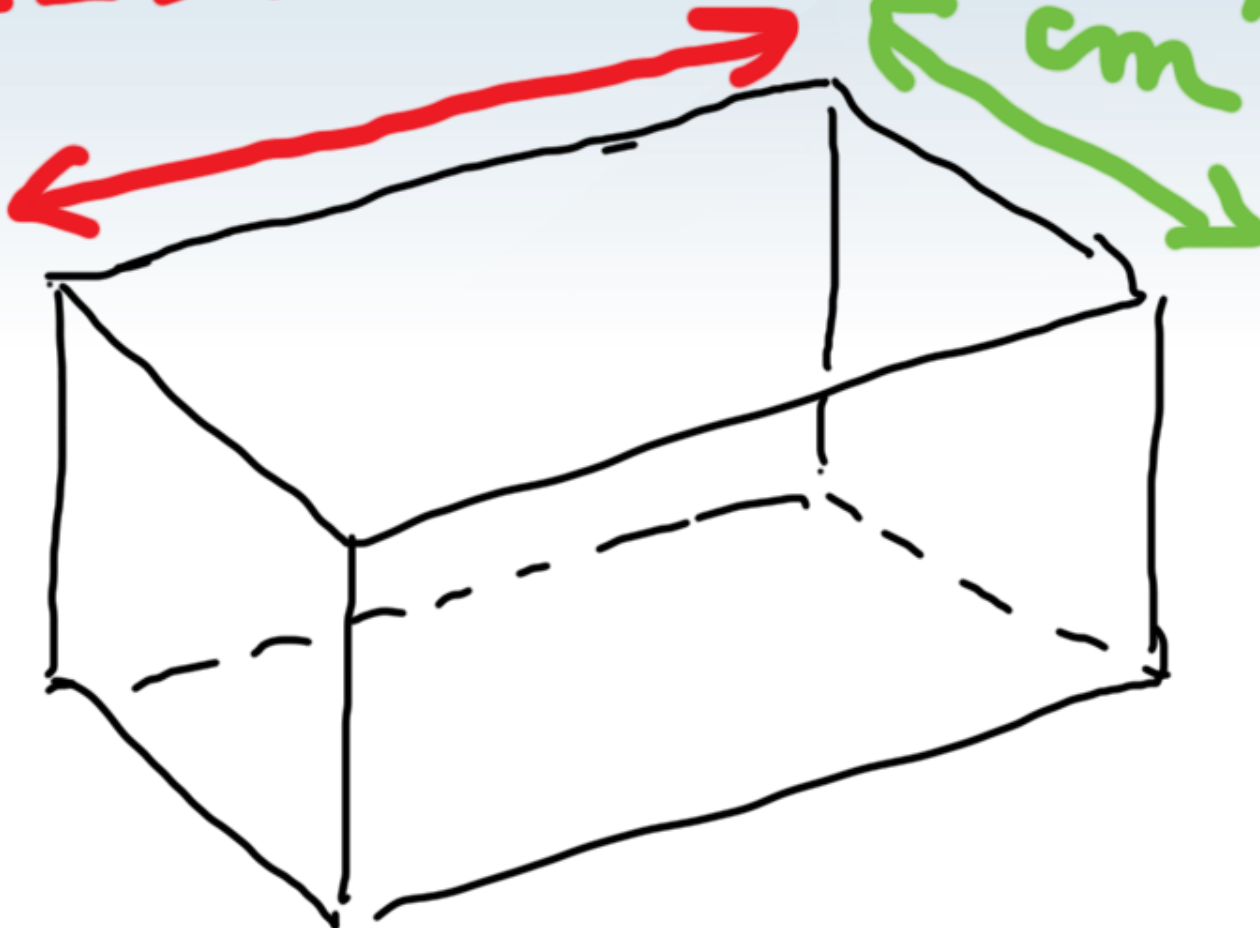
$h(\text{empty}) = 0.9 \text{ cm}$



VOLUME OF THE BALL

$L = 35 \text{ cm}$

$l = 24 \text{ cm}$



VOLUME OF THE BALL



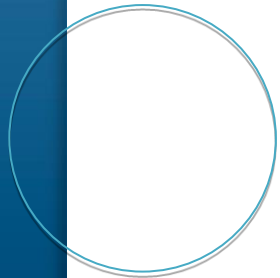
$$V(\text{full}) = 35 \times 24 \times 5.6 = 4704 \text{ cm}^3$$

$$V(\text{full}) = 4.70 \text{ L}$$



$$V(\text{empty}) = 35 \times 24 \times 0.9 = 756 \text{ cm}^3$$

$$V(\text{empty}) = 0.76 \text{ L}$$



$$V(\text{air}) = 4.70 - 0.76 = 3.94 \text{ L}$$

$$V(\text{air}) = 3.94 \text{ L}$$

DENSITY OF THE AIR



$$d = m/v(\text{air})$$

$$d = 5.2/3.94$$

$$d = 1.32 \text{ g/L}$$

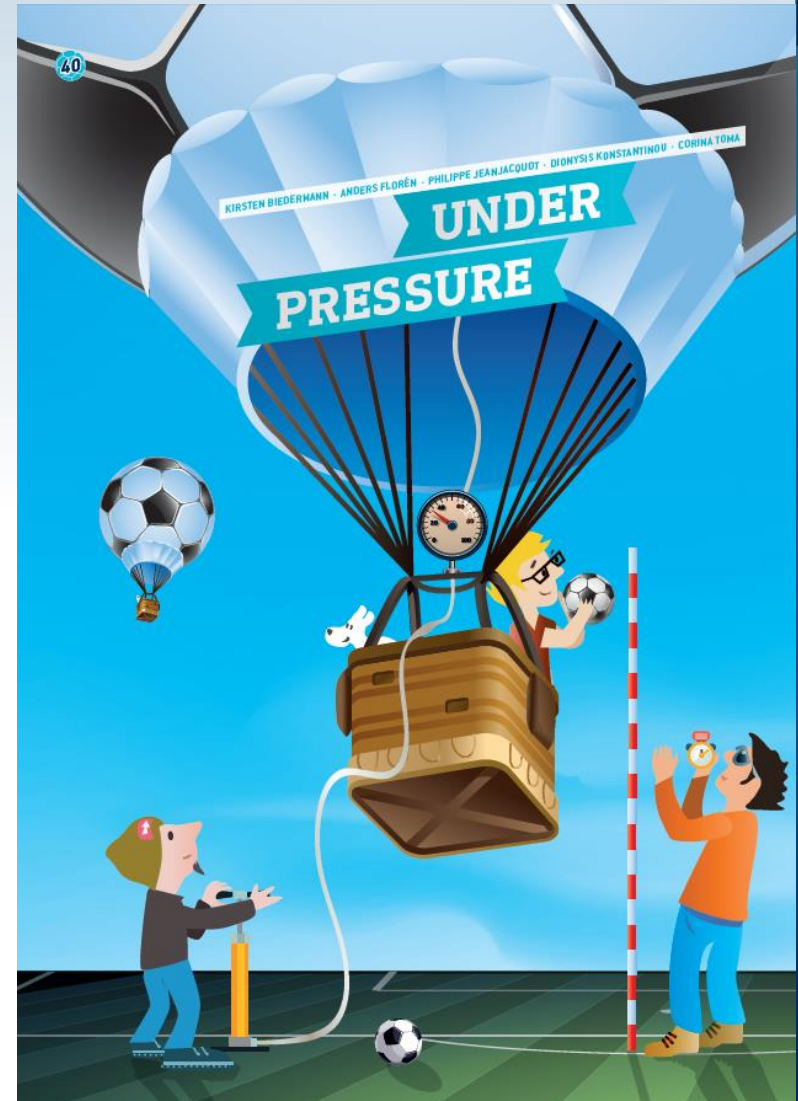
The real value is 1.2 g/L at the temperature of the measure (25°C)

The errors can occur principally from the measure of the volume (to get a good empty ball) and also from the measure of the pressure

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★ BOUNCE



Dependence of the bouncing height with the pressure



For an elastic collision with the ground the coefficient of restitution is:

$$e = \frac{v_{\text{separation}}}{v_{\text{approach}}}$$

$$mgh_1 = \frac{mv_{\text{approach}}^2}{2}$$

the ball is falling down from the height h_1

$$mgh_2 = \frac{mv_{\text{separation}}^2}{2}$$

after the collision the ball can reach the height h_2

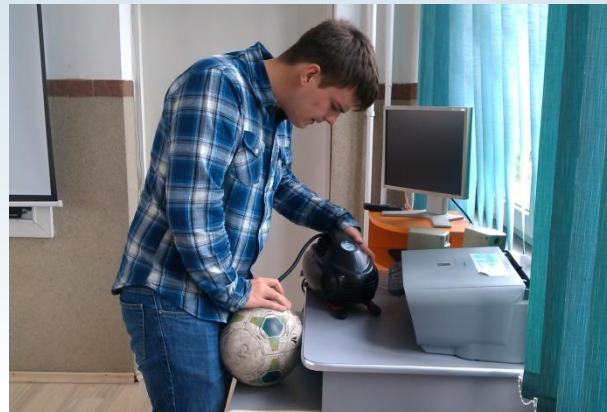
$$e = \sqrt{\frac{h_2}{h_1}}$$

What you need?



- ★ Football
- ★ Pump with manometer
- ★ Measuring tape or a marked paper tape that can be stuck on the wall
- ★ Smartphone
- ★ VidAnalysis application

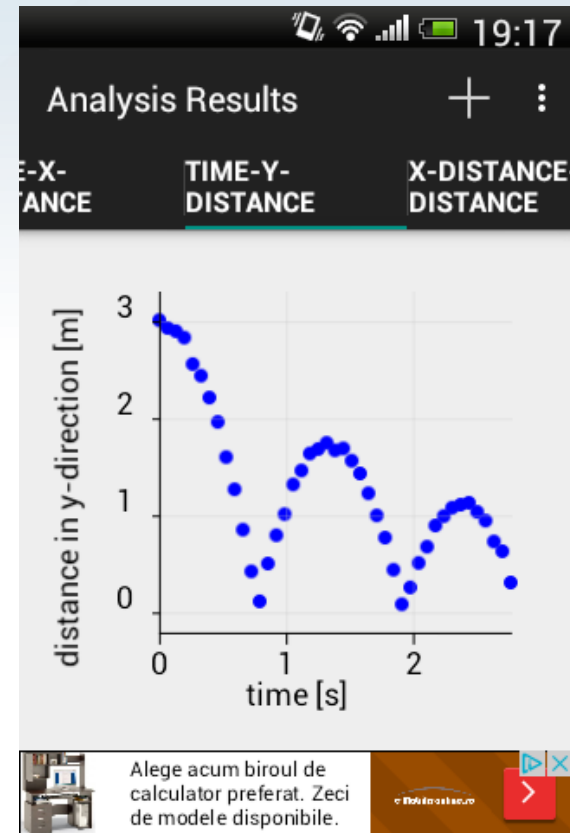
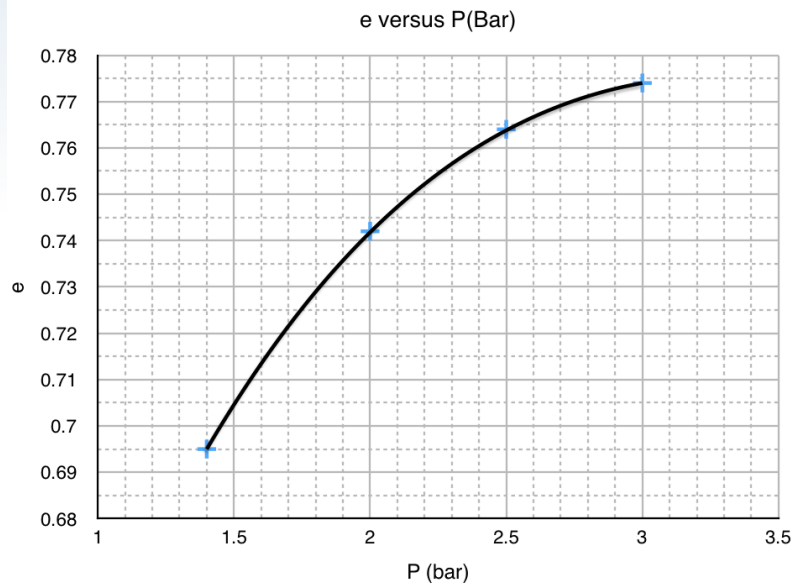
What to do?



Results



Reading the heights from the video using VidAnalysis



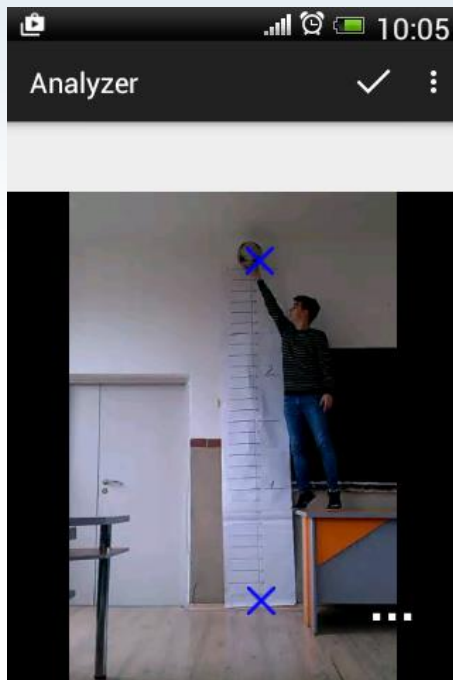
VidAnalysis



<https://play.google.com/store/apps/details?id=com.vidanalysis.free>

Record a video and import into the app.

Calibrate the video: mark the length of the known distance in the frame and insert the real length



VidAnalysis



Pick the origin of the coordinate system.

Mark the ball by tapping on it in every frame.

Diagrams are generated automatically:

$x = f(t)$, $y = f(t)$ and $y = f(x)$

$v_x = f(t)$ and $v_y = f(t)$

Data table

