	TEAM: 9	
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Smashing! Real-world clashes into physics classes	Italy	Anna Dall' Aglio Anna Santi Arianna Tanesini
EXPERIMENT: Collision of a basketball		

1. ORIENTATION

Belgians:

1.1. Research question:

What are the effects of a collision on a basketball when we vary the pressure inside of it?

Sub-questions:

1. When the pressure is increased how does the kinetic and gravitational potential energy change?
2. Does the ball lose more or less energy due to the collision?
3. What is the effect of a change in pressure on the velocity of the ball during and after the collision?
4. What influence does an increase of pressure have on the maximal height the ball reaches after the collision?

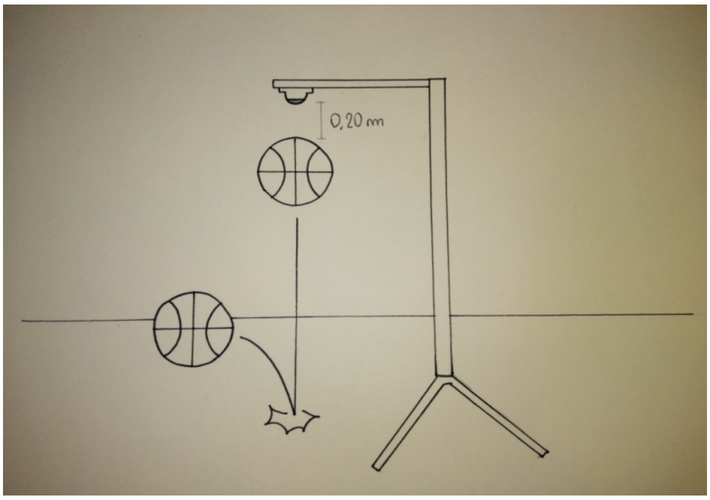
Sub-questions

1. Before the collision, the ball with more pressure will have the same kinetic and gravitational potential energy as the ball with less pressure. When the ball is dropped, the gravitational potential energy will be converted to kinetic energy, and the velocity will increase. At the moment of the collision, the ball with the least amount of pressure will deform, and energy will be lost to the deformation. This will cause the ball to have less kinetic energy as well as less gravitational potential energy after the collision.
2. When you increase the pressure of the ball, the ball won't deform as much during the collision. Because of this, a ball with higher pressure won't lose as much energy during the collision as a ball with lower pressure.

3. A ball with a higher pressure will have a higher velocity after the collision than a ball with a lower pressure. Due to the ball's higher pressure, it will have more kinetic energy than a ball with a low pressure because it won't lose as much energy to the deformation of the ball.
4. After the collision, the kinetic energy will be converted back to gravitational potential energy. As a result, the ball will gain height. Because the ball with higher pressure doesn't lose as much energy to the deformation of the ball, it will gain more height due to its greater gravitational potential energy.

Italians:

2. PREPARATION

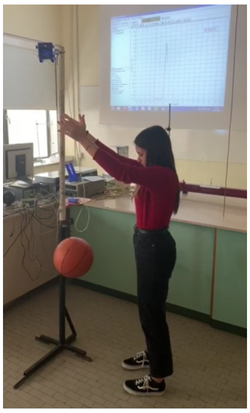


2.1. **Material**:

1. Basketball
2. Compressor
3. Metal support
4. Motion sensor
5. Computer
6. Scale

2.2 Method:

1) Attach the motion sensor to the top of the metal support.
2) Weigh the ball using the scale to calculate the change in the ball's momentum.
3) Inflate the ball with the compressor (make sure the pressure resides around 1 bar) and position it 20 cm underneath the sensor.
4) Support the ball with one hand after which you drop the ball which causes it to continually bounce off the floor until it reaches standstill.
5) By utilising the position sensor, you can obtain the speed, acceleration, position and the amount of time that ball falls.



6) Through the values found, three graphs are composed: position-time, speed-time and acceleration-time. With these values we can calculate the kinetic and gravitational potential energy of the ball and its impulse.
7) Repeat this process for different values of pressure within the ball (preferable using a scale so that the pressures are relative to one another and easy to compare).

3. DATA ANALYSIS and DISCUSSION

3.1. Observations and Measurements:

Belgians:

1. Basketball 1 (mass: 600 gr) with the highest pressure:

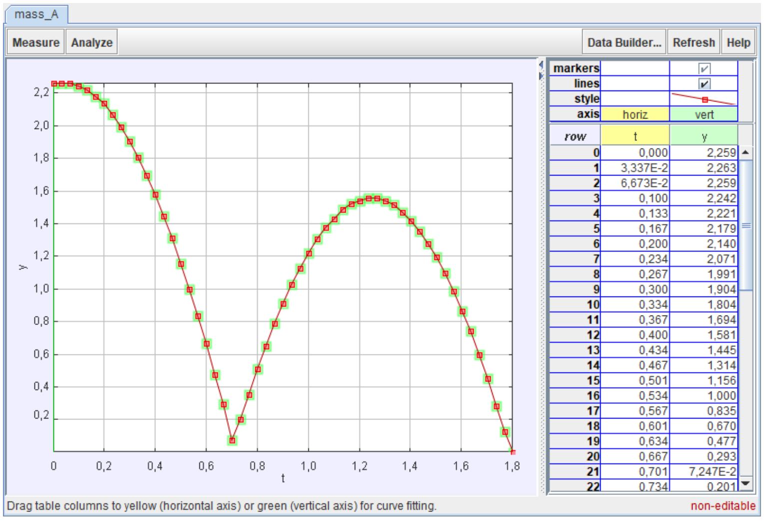


Fig. 1. Position-time graph of basketball 1

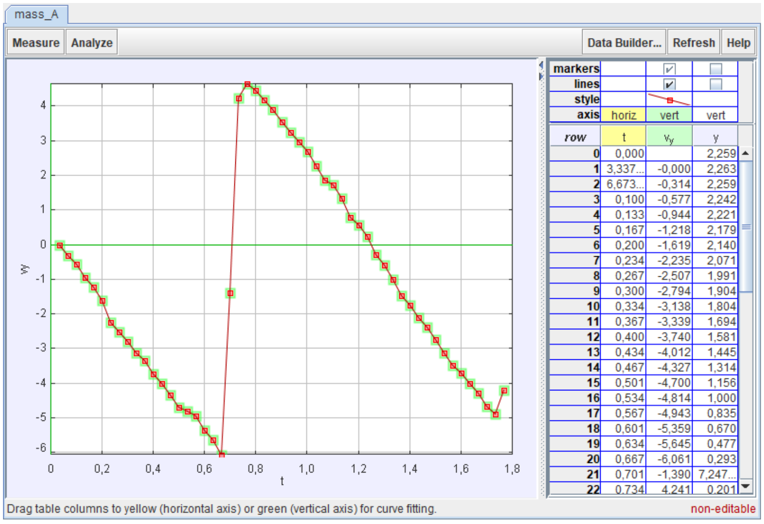


Fig. 2. Speed-time graph of basketball 1

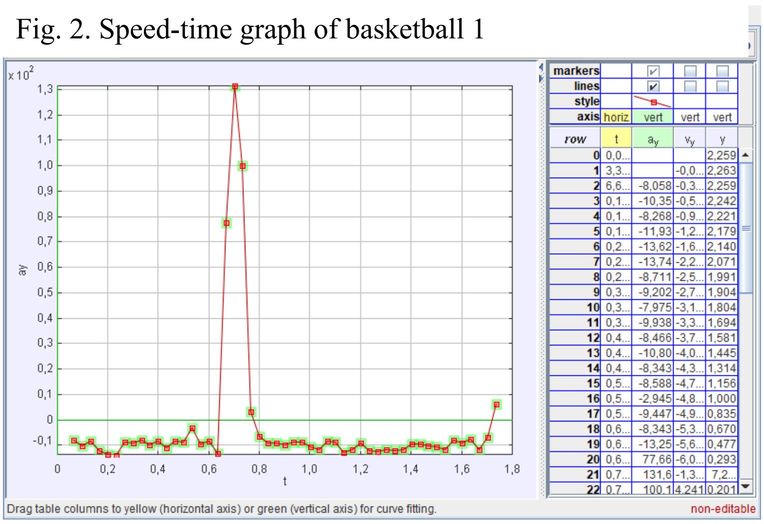


Fig. 3. Acceleration-time graph of basketball 1

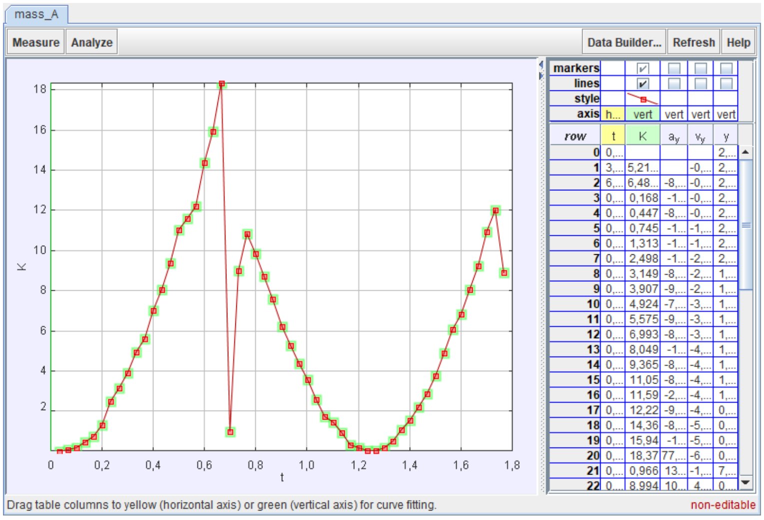


Fig. 4. kinetic energy as a function of time of basketball 1

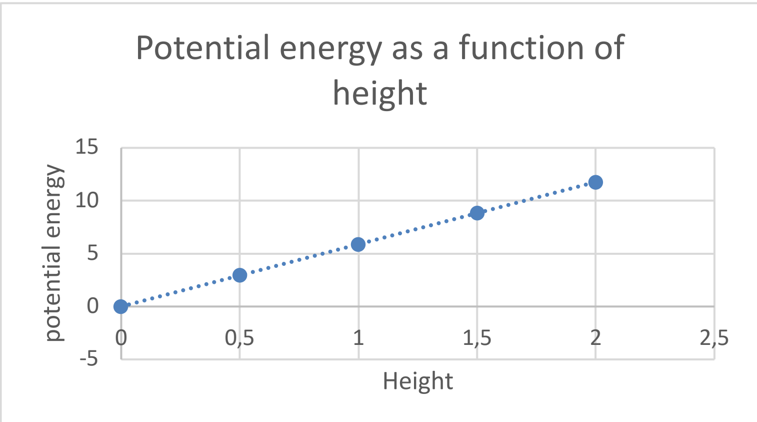


Fig. 5. Potential energy as a function of height of basketball 1

2. Basketball 2 (mass 594 gr) with the second highest pressure:

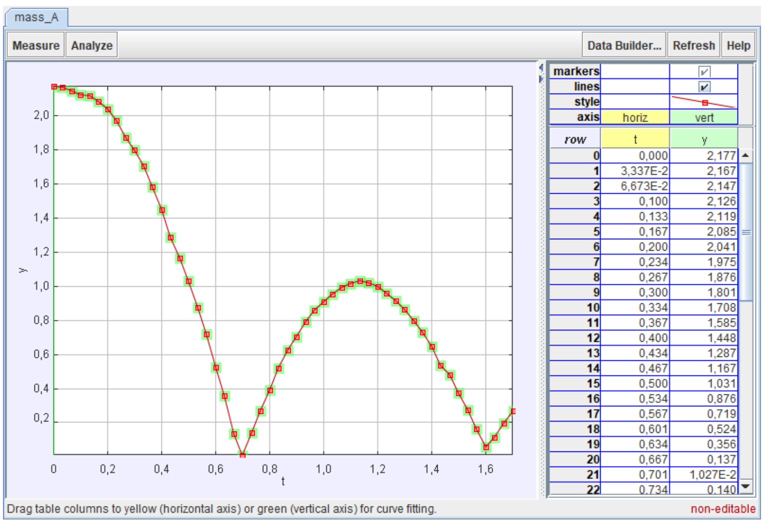


Fig. 6. Position-time graph of basketball 2

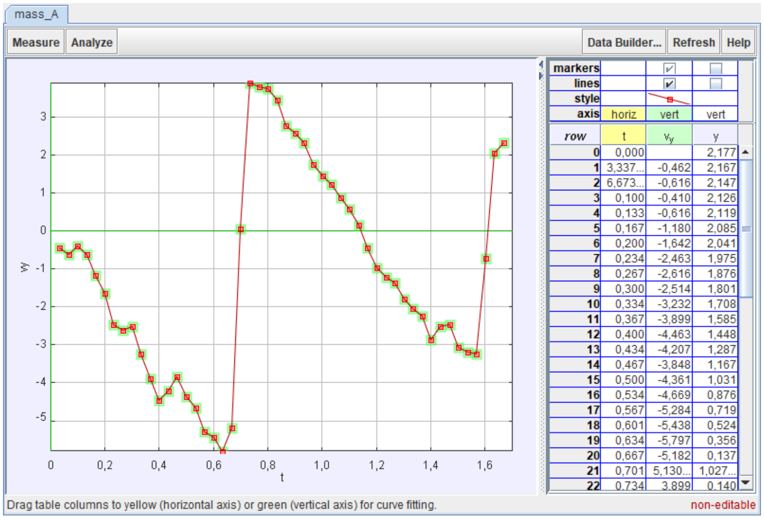


Fig. 7. Speed-time graph of basketball 2

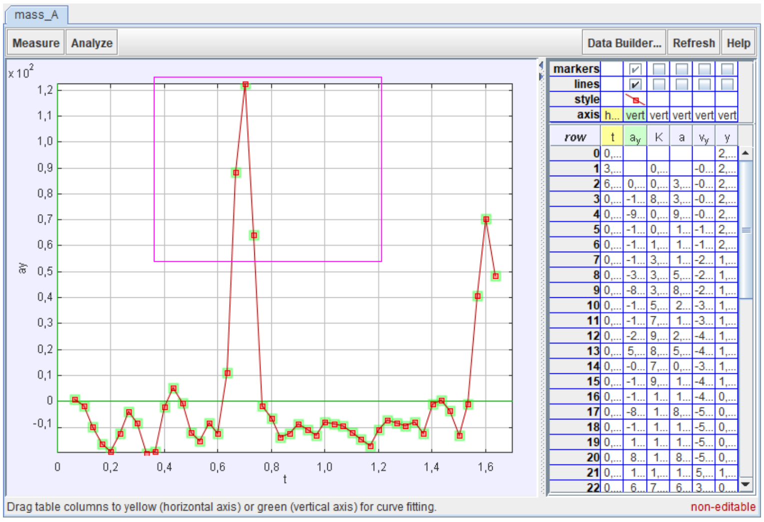


Fig.8. acceleration-time graph of basketball 2

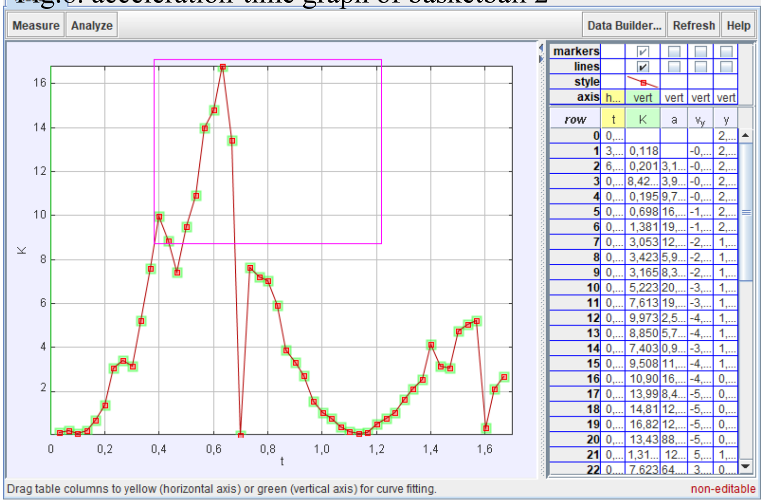


Fig. 9. Kinetic energy as a function of time of basketball 2

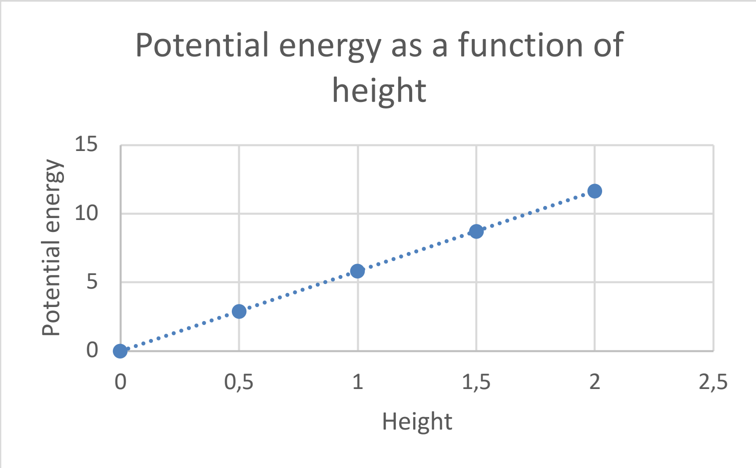


Fig. 10. Potential energy as a function of height of basketball 2

3. <u>Basketball 3 (mass 591 gr) with the lowest pressure:</u>

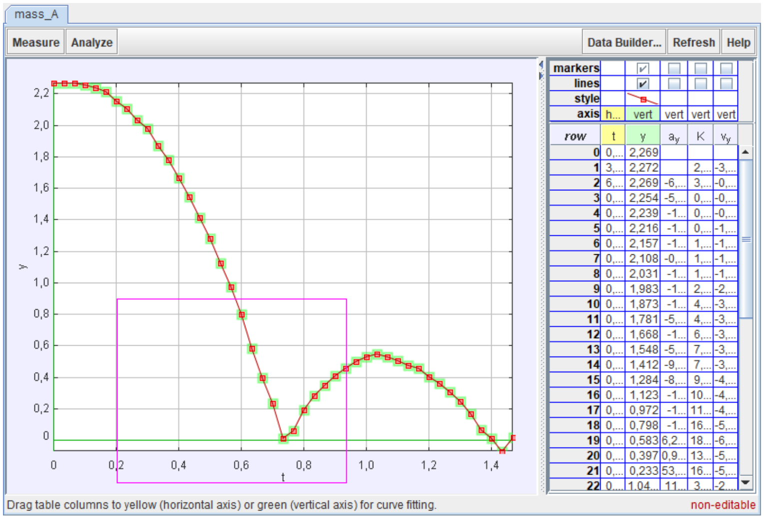


Fig. 11. Position-time graph of basketball 3

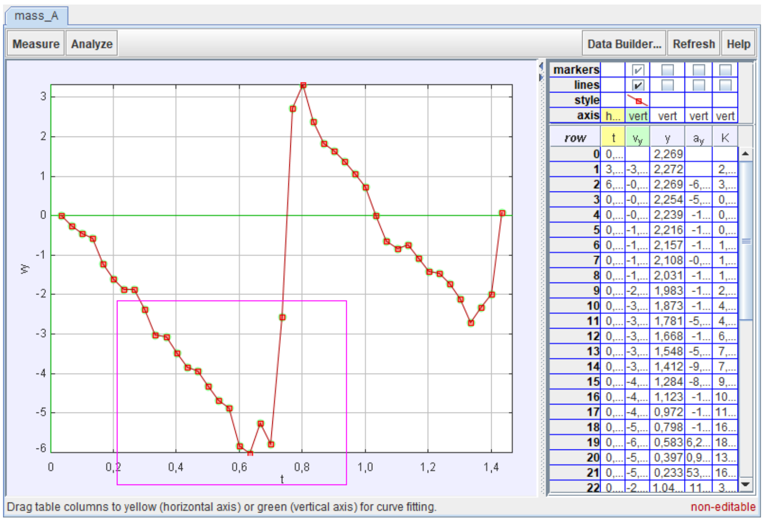


Fig. 12. Speed-time graph of basketball 3

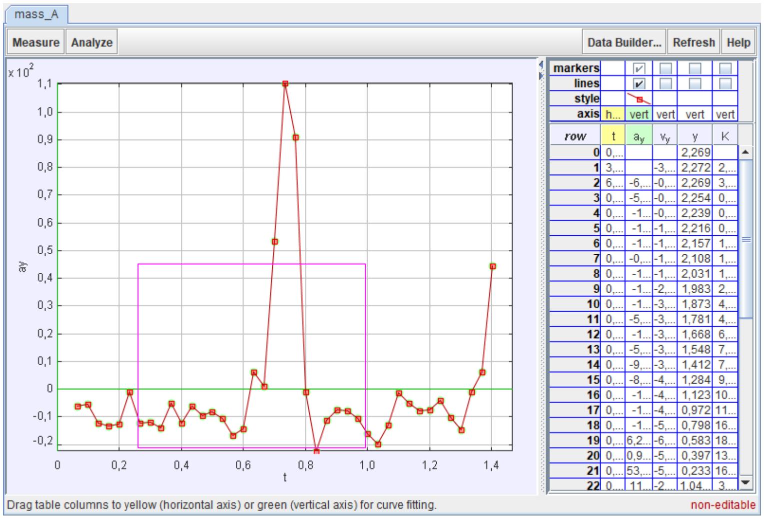


Fig. 13. Acceleration-time graph of basketball 3

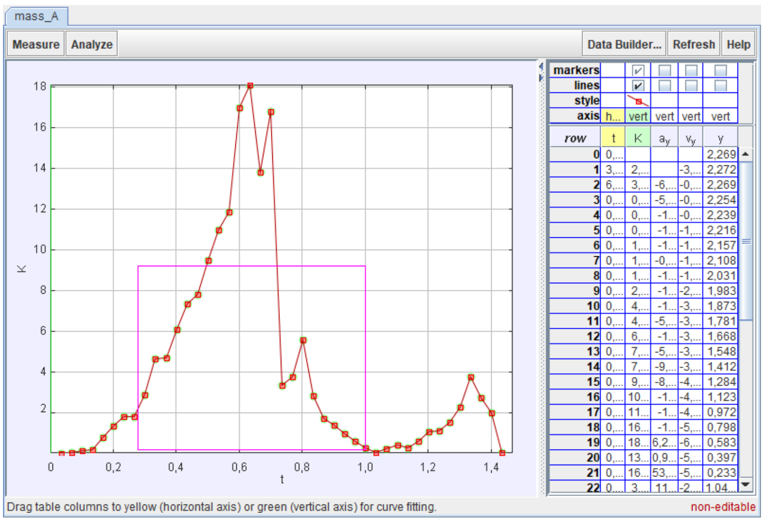


Fig. 14. Kinetic energy as a function of time of basketball 3

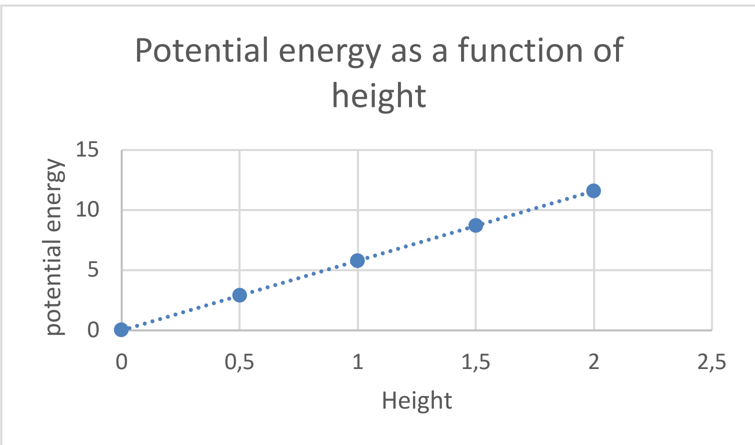


Fig. 15. Potential energy as a function of height of basketball 3

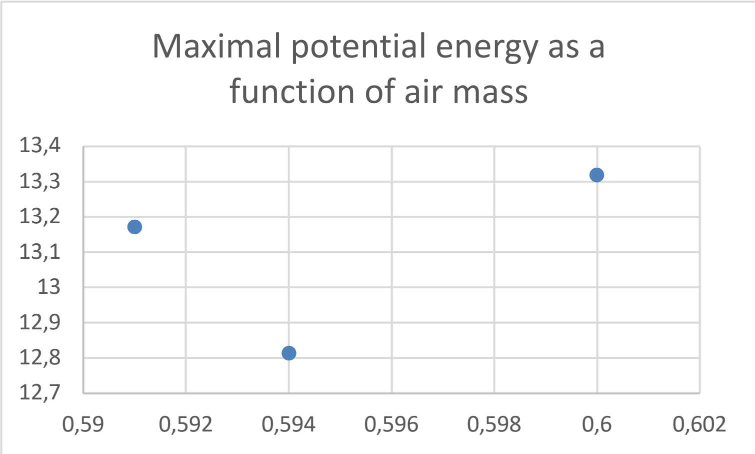


Fig. 16. Maximal potential energy in function of air mass

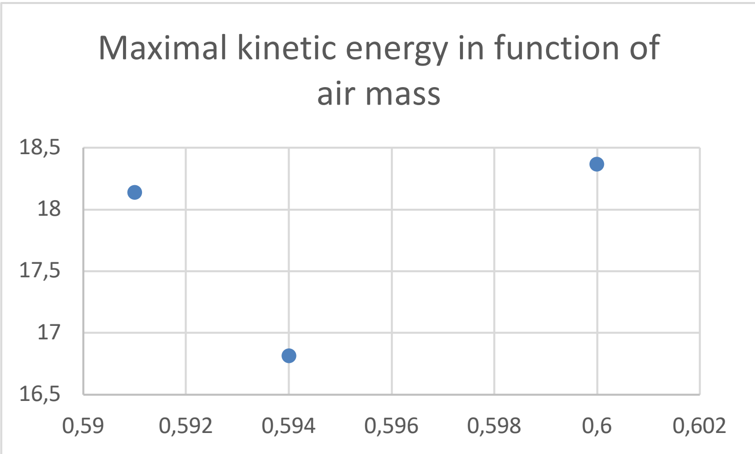


Fig. 17. Maximal kinetic energy in function of air mass

Due to the small difference in air mass between the basketballs, we were unable to find a mathematical connection between the maximal potential and kinetic energy of the basketballs.

Italians:

1° TEST(the pressure of the ball is about 1 bar)

The graph position vs. time shows the position with respect to the motion sensor, placed above the ball. We have transformed the positions to give the height above the ball's lowest position (where it bounces against the floor) as can be seen in the tables. In the same way, the velocities listed in the tables are taken positive when the ball is moving upwards, as opposed to the signs seen in the graphs velocity vs. time.

We have calculated various physical quantities at different positions (A, B-, B+, C, D-, D+, E), defined as:

A = start point

B- = point just before the first rebound

B+ = point just after the first rebound

C= maximum height after the first rebound

D- = point just before the second rebound

D+ = point just after the second rebound

E = maximum height after the second rebound

The positions are also indicated in the position vs. time and the velocity vs. time graphs.

	T(s)	H(m)	Ep(J)	Ek(J)	Em(J)	V(m/s)
A	1,20	1,48	8,47	0	8,47	0,0
B-	1,75	0,00	0,00	7,88	7,88	-5,2
B+	1,75	0,00	0,00	4,67	4,67	4,0
C	2,20	0,96	3,89	0,00	5,49	0,0
D-	2,65	0,00	0,00	4,67	4,67	-4,0
D+	2,65	0,00	0,00	3,18	3,18	+3,3
E	3,00	0,64	3,66	0,00	3,66	0

Mass of the ball= 583,4g= 0,5834 kg

Gravitational potential energy

EpA= hA*m*g= 1,48m* 0,5834 kg* 9,81 N/Kg = 8,47 J

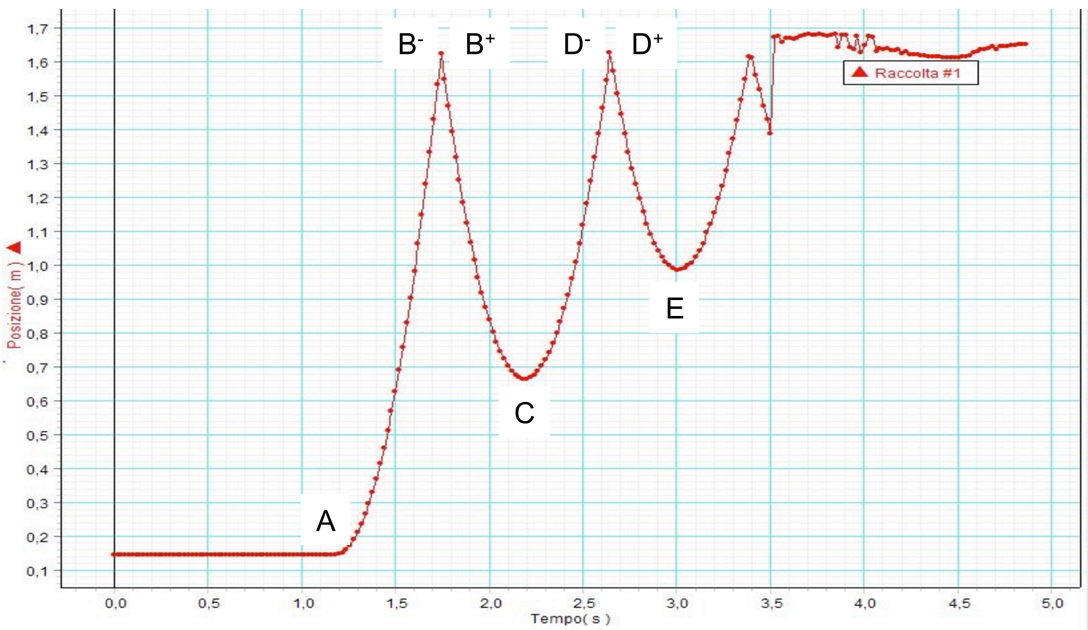
EpC= hC*m*g= 0,96m* 0,5834 kg* 9,81 N/Kg = 5,49 J

EpE= hE*m*g= 0,64m* 0,5834 kg* 9,81 N/Kg = 3,66 J

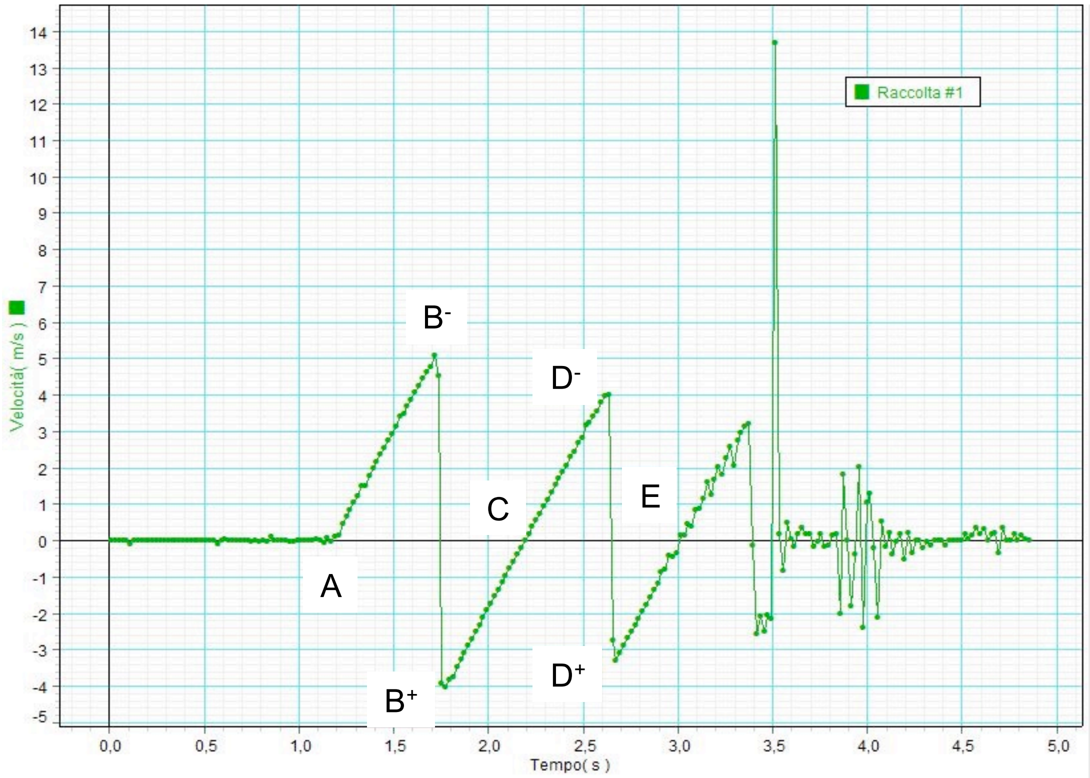
One can notice that the mechanical energy at point A (determined by Ep) is not equal to the mechanical energy at point B^- (determined by Ek), as it should be. The same thing hold for the points B^+-C-D^- and D^+-E. We attribute this effect to a shortcoming of the acquisition system: the motion sensor measures the positions and the software then calculates the velocities as an average value using more than one time interval. This means that the velocities seen in the velocity vs. time graphs, just before the bounce, is slightly lower than the real instant velocity at the moment of the bounce. Therfor, in the sequel, we use the value determined by Ep

We can see that during the collision there was a dispersion of energy.

Graph position-time:



Graph speed-time:



Energy dissipated:

First bounce B^--B^+:

EmA = 8,47 J

EmC = 5,49 J

%ΔEm = 100%*(EmA – EmC) / EmA = 35%

Second bounce D^--D^+:

EmC = 5,49 J

EmE = 3,66 J

%ΔEm = 100%*(EmC – EmE) / EmC = 33%

2° TEST(the ball has been slightly deflated)

	T(s)	H(m)	Ep(j)	Ek(j)	Em(j)	V(m/s)
A	0,75	1,45	8,29	0	8,29	0
B-	1,25	0,00	0,00	3,6	3,6	3,52
B+	1,25	0,00	0,00	7,88	7,88	-5,2
C	1,65	0,76	4,34	0	4,34	0
D-	2,05	0,00	0,00	3,4	3,4	-3,4
D+	2,05	0,00	0,00	0	0	0
E	2,35	0,40	2,28	0	2,28	0

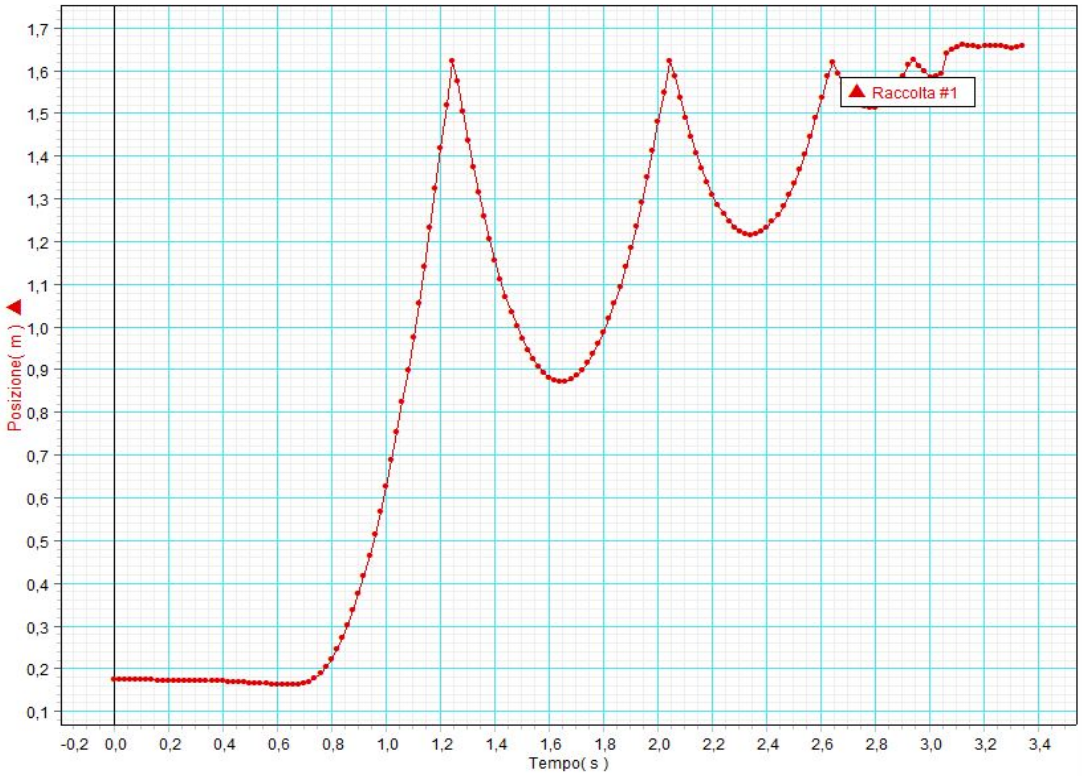
H(m) = Hi – Hf = 1,62 – x

Gravitational potential energy

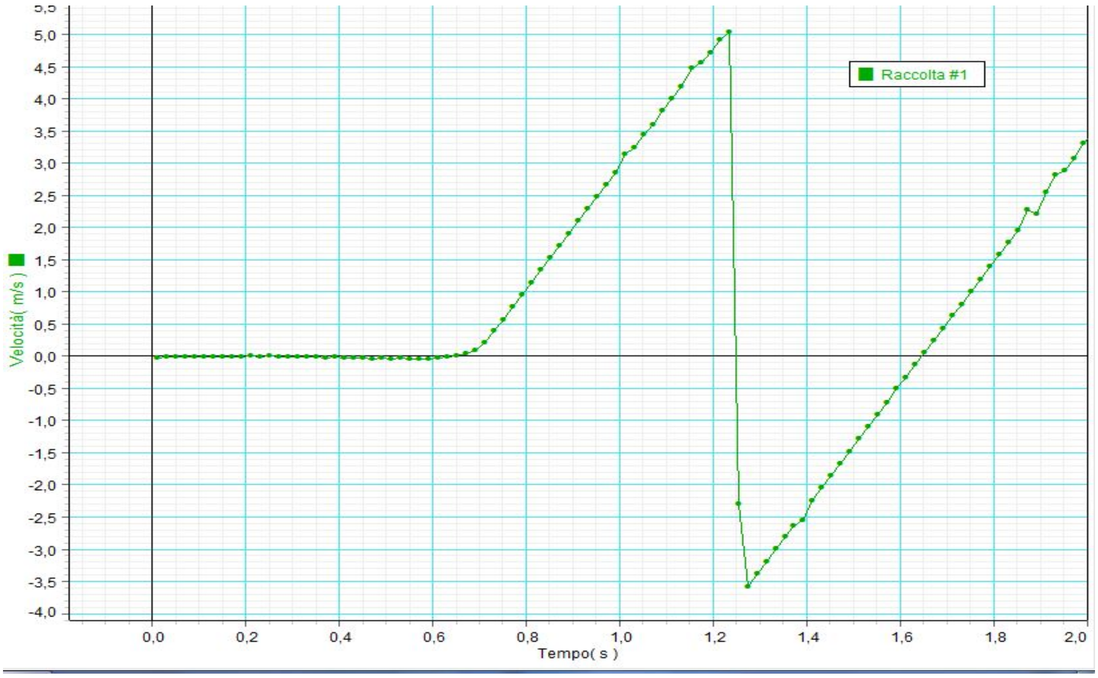
Epi= hi*m*g= 1,44m* 0,5834 kg* 9,81 N/Kg = 8,24 J

Epf= hf*m*g= 0,38m* 0,5834 kg* 9,81 N/Kg = 2,17J

Graph position-time:



Graph speed-time:



Energy dissipated:

First bounce B^{-}-B^{+}:

EmA = 8,29 J

EmC = 4,34 J

%ΔEm = 100%*(EmA – EmC) / EmA = 48%

Second bounce D^{-}-D^{+}:

EmC = 4,34 J

EmE = 2,28 J

%ΔEm = 100%*(EmC – EmE) / EmC = 47%

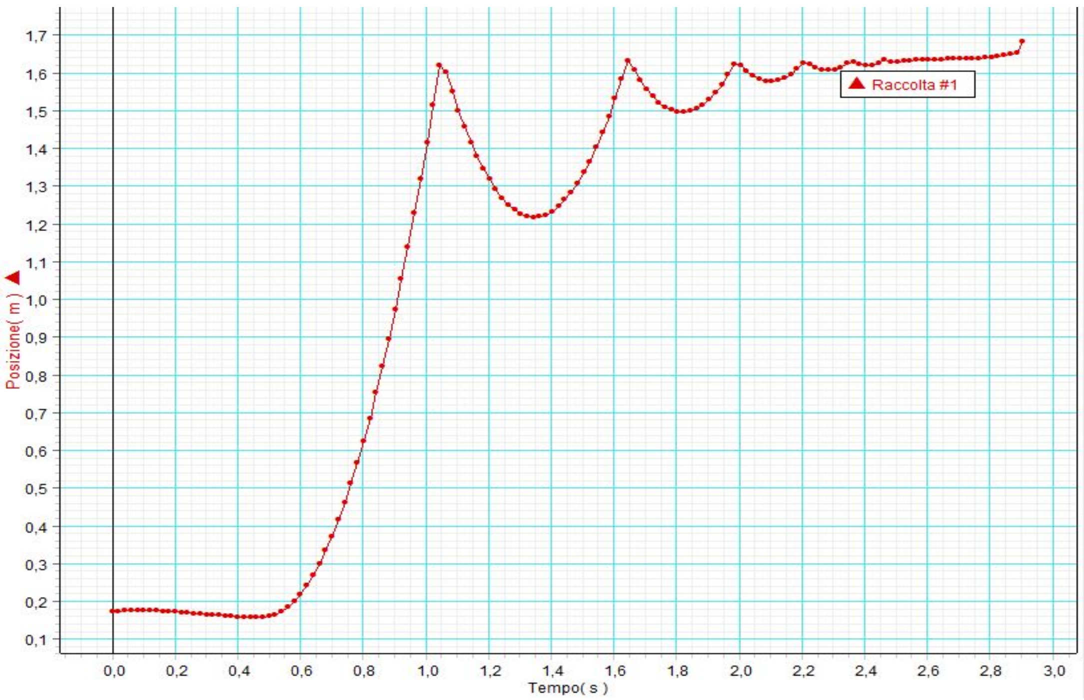
Also in this test we can see that the mechanical energy determined in the various points is not the same. Therefore we can deduce that also in this case there is a defect in the acquisition system by the sensor.

We can see that during the collision there was a dispersion of energy.

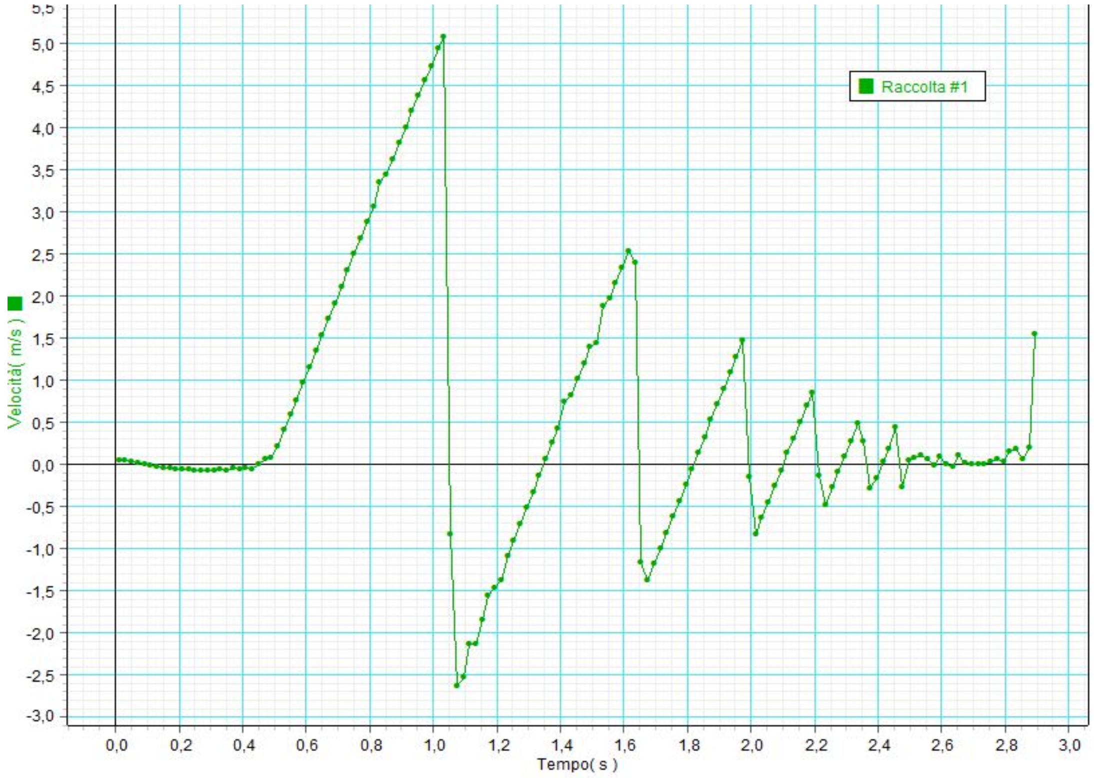
3° TEST(the ball was deflated again)

	T(s)	H(m)	V(m/s)	Ep(j)	Ek(j)	Em(j)
A	0,55	1,42	0	8,12	0	8,12
B-	1,05	0,00	-5,2	0	7.88	7,88
B+	1,05	0,00	2,52	0	1,85	1,85
C	1,35	0,40	0	2,28	0	2,28
D-	1,65	0,00	-2,50	0	1,8	1,8
D+	1,65	0,00	1,48	0	0,63	0,63
E	1,85	0,12	0	0,68	0	0,68

Graph position-time:



Graph speed-time:



Energy dissipated:

First bounce $B^- - B^+$:

EmA = 8,12 J

EmC = 2,28 J

%ΔEm = 100%*(EmA – EmC) / EmA = 72%

Second bounce $D^- - D^+$:

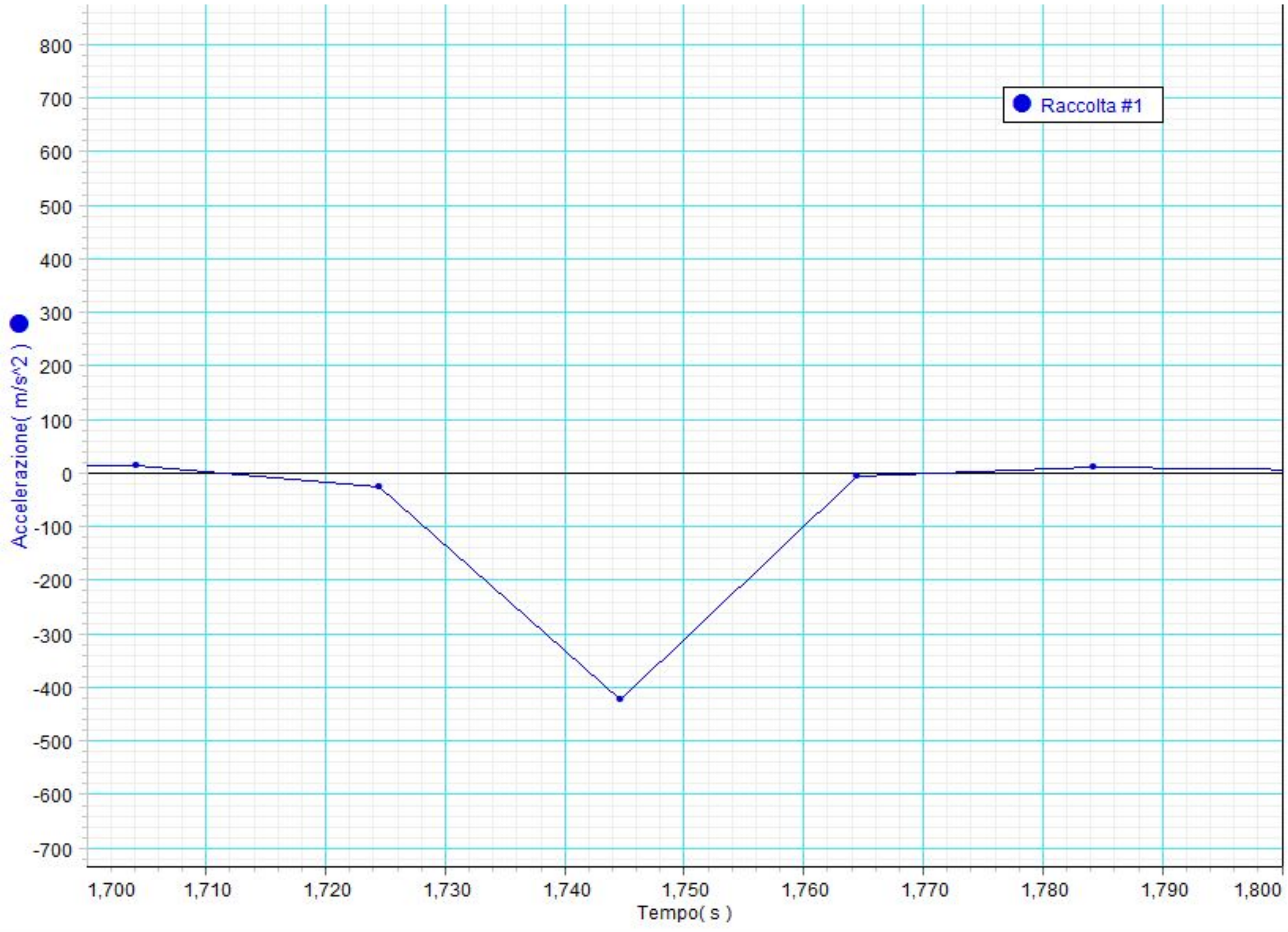
EmC = 2,28 J

EmE = 0,68 J

%ΔEm = 100%*(EmC – EmE) / EmC = 70%

(we can see that during the collision there was a dispersion of energy)

Through this graph we calculated the area of the triangle that was created and then we calculated the impulse. This graph was taken from the first test



Area: ½*a*Δt = ½*420* (1,740 – 1,700) s = ½*420*0,04s = 8,4

Impulse= m*A = 0,5834 Kg* 8,4 = 4,9

Linear moment:

Δp = m* Δv = 0,5834 kg*(5 - (-4)) = 5,25= 5,3

These two quantities were calculated through the data obtained from the 1st test

3.2. Discussion:

Belgians:

1. Basketball (mass: 600 gr) with the highest pressure:

The first graph shows the x(t) graph. It doesn't start from the beginning because we dropped it from about 2 metres. The graph decreases sharply until the ball touches the ground. At that point x is approximately equal to zero. This happens at 0.7s. The ball bounces back up again, causing x to increase again. When the ball reaches its highest possible point subsequent to the collision (x=1.58), x will start to decrease again and repeats this process until the ball reaches standstill.

The second representation shows the v_y(t)-graph. The balls speed before it begins falling is 0 because it's in rest. Afterwards it's pace rapidly becomes negative, but in practice, it's velocity increases. This phenomenon was induced by the inverted fall of the ball relative to the upright y-axis. When the ball reaches the ground its speed immediately becomes positive. The velocity becomes inversed because the its direction is parallel to the y-axis, but its sentence is turned around. The higher the ball flies, the larger its speed. At t=1.25, its velocity is equal to zero. At this moment the ball starts falling back down and the speed is once again negative.

The third graph represents the a_y(t) graph. It goes into sub-zero whenever the ball falls down because the y-axis is oriented upwards, and the ball quickens downwards. Soon after the collision, the acceleration becomes positive because the ball accelerates upwards. But at t=0.7, the ball slows down and thus the a_x graph drops.

The fourth graph describes the kinetic energy during the fall and collision. At t=0, the kinetic energy is also equal to 0. The ball hasn't obtained any speed yet. When the ball starts falling and thus gets velocity, the kinetic energy increases. This energy is at its highest point right before the ball touches the ground. When the ball touches the ground, the kinetic energy is as good as zero. After the collision, the ball regains kinetic energy and thus speed, but immediately start decreasing as the ball moves upwards again. It is caused by the conversion into potential gravitational energy. Around point in time (t=1.3s), all kinetic energy is converted into potential energy. The ball will fall down again, and the potential energy is converted once again into kinetic energy.

The graph of the potential energy rises when the ball goes up and falls when the ball goes down. It's caused by the rise in height whenever the ball rises and falls. While it falls, the maximum potential energy at is completely converted into kinetic energy. When the ball goes up, it goes the other way around.

2. Basketball (mass 594 gr) with the second highest pressure:

The graphs of basketball 2 and 3 have a similar explanation as for basketball 1.
The difference in values on the other hand is more important to discuss.

Basketball 2 hits the ground for the first time around t=0.734s. According to values in the table and graph, basketball 1 hits the ground a slight amount later than basketball 2, but the difference is disposable. After the second collision there, the difference suddenly increases by a massive amount. Basketball 2 (t=1.60) hits the ground 0.20 seconds earlier than basketball 1 (t=1.80). This time difference is caused by the second ball not being capable of reaching the same height, it only reaches about 1m.

On the graph, you can see that the first ball reached a higher speed just before the collision than the second ball, the same counts for the time after the collision, ball 2 reaches a lesser speed. In other words, the speed that the ball reaches are generally lower.
Just after the second ball touches the ground, its acceleration reached is less than the acceleration achieved by ball 1.

The maximum reached by basketball 2 on the kinetic energy graph is lower than its counterpart of the first ball. The kinetic energy post-collision is smaller, about 7.25J. The same counts for the second collision. During the collision a lot of energy is lost to the deformation of the ball. The second ball has a lower pressure and therefore becomes more deformed.

The maximum potential energy of ball 2 is less than ball 1. It is caused by the mass of ball 2 being smaller than the mass of ball 1. Mass, namely, plays an important role in the formula of potential energy (Epot=m*g*h). The difference in mass is miniscule thus the difference in potential energy isn't much larger.

3. Basketball (mass 591 gr) with the lowest pressure:

The time difference between ball 1, 2 and 3 is once again disposable (t=0.742s). After the third collision the difference once again increases by a massive amount. Basketball 3 (t=1.40s) hits the ground 0.20 seconds earlier than basketball 2 (t=1.60s) and 0.40 seconds earlier than basketball 1 (t=1.80s). This time difference is caused by the third ball not being capable of reaching the same height, it only reaches about 60cm.

On the graph, you can see that the first ball reached a higher speed just before the collision than the third ball, the same counts for the time after the collision, ball 3 reaches a lesser speed. In other words, the speed that the ball reaches are once again generally lower.

Just after the second ball touches the ground, its acceleration reached is less than the acceleration achieved by ball 1.

The maximum reached by basketball 3 on the kinetic energy graph is lower than its counterpart of the first and second balls. The kinetic energy post-collision is smaller, about 4.11J. The same counts for the second collision. The maximum potential energy of ball 3 is less than ball 1 and 2 due to the smaller mass of ball 2.

4. REFLECTION

4.1. **Conclusion**:

Belgians:

1. The kinetic and potential energy achieved after the collision is greatest at the ball with the highest pressure. The kinetic energy obtained before the collision is also highest at the ball with the highest pressure.
2. The ball loses more energy during the collision when the pressure is lower.
3. The speed of the ball with the lower pressure is lower than the speed of the ball with the higher pressure.
4. When the pressure in the ball is higher, the ball goes higher after the collision.

Italians:

By observing the graphs, it is possible to see that in any case there is no conservation of momentum because the initial kinetic energy is different from the final one. By comparing the graphs of the cases examined it is possible to note that where the pressure inside the ball is greater, more rebounds are detected, while when the pressure in the ball is lower the kinetic energy is exhausted in less time and the ball stops.

4.2. **Comparison** of the results of the different countries:

Belgians:

By looking at the graphs and tables, it's obvious that the Belgians and the Italians got approximately the same results. Our exact measurements such as height, kinetic and gravitational potential energy aren't the same due to our different experiments. However, both countries clearly noticed that the kinetic and potential energy achieved after the collision is greatest with the ball which has the highest pressure. Also, the ball lost most energy during the collision when the pressure was lower and the ball with the lowest pressure had a lower speed than the ball with the highest pressure after the collisions for both the Belgians and Italians. The ball with the highest pressure therefore went highest for both experiments. We can conclude that our results are accurate, as both countries had approximately the same results.

4.3. **Reflection:**

We worked well together and the experiments went very smoothly. We were always able to communicate efficiently and work out who would do what. It was a successful project that both countries enjoyed contributing to.