

Friday 10th March - Materials Decathlon - Challenge n°5 - 40'

QUANTITATIVE RESTITUTION COEFFICIENT

Do you remember the challenge CH5 (see MoM resources at the bottom) with the happy (H) and sad (S) ball? Let's do some quantitative measurements by taking videos of the bouncing/rolling balls. Split the team into two groups: **group A** will deal with bouncing and **group B** with rolling. Both groups should take videos of balls moving and elaborate them using Tracker software.

1. Group A - Comparison of Neoprene (H) and Norbonene (S) balls bouncing

- Put yourself in front of the ball and the meter sticker in order to shoot a clear neat video. Check that graduation on the meter is visible in the video. If not, just stick some coloured tape strip of known length on the ruler. This will be useful for further calibration.
- Drop the balls one after the other from approx. 100 cm height. Possibly record in the same video.
- Upload the video to Tracker¹ and analyze it to deduce the ratio h_2/h_1 where:

$$CoR = \sqrt{\frac{\text{bounce height}}{\text{drop height}}}$$

h_2 = height reached by the ball after the first bounce;

h_1 = initial height (100 cm) from which the ball has been dropped.

- The square root of such ratio is the **Coefficient-of-Restitution** (ϵ). If this is 1 then the collision is **perfectly elastic**. Actually it will be <1 , meaning that the collision is **partially inelastic** and energy has been dissipated. This would be true only if the bouncing is perfectly perpendicular to the floor, so be careful to achieve this condition as much as possible [Do some trials before starting the experiment]. Calculate the **Coefficient-of-Restitution** (ϵ) for both balls and fill in **Table A** with all the data collected and/or calculated.

2. Group B - Comparison of Neoprene (H) and Norbonene (S) balls rolling

- Put yourself with the camera in front of one of the lateral sides of the two ramps. Put the meter sticker between the two ramps in order to shoot a clear neat video. Check that graduation on the meter is visible in the video. If not, just stick some coloured tape strip of known length on the ruler. This will be useful for further calibration.
- Let the balls roll down the ramps starting at the same moment. [Remember to start always from the same point.] Possibly get both ball's launches in the same video.
- Upload the video to Tracker and analyze the motion of the two balls. Produce the s-t (position versus time) **graph**. In particular deduce the **Final Velocity** of the two balls: fill in **Table B** with all the data collected and/or calculated.

3. BOTH Group A and Group B - Influence of the temperature

- Repeat all the above steps but with the balls at a different temperature, the same for both balls. [You can change the temperature of the balls putting them for some time – 1 or 2 minutes should be enough – into hot water]; Write down the temperature of the balls. [Actually T of the water: be quick in dropping the balls after you have taken them out from the water: they are cooling fast!].
- Repeat the experiment with as many different temperatures as you can. Plot a graph of **Coefficient-of-Restitution** (ϵ) VS **Temperature** [Group A] or **Final Velocity** VS **Temperature** [Group B]. Is there any relationship?



OUTPUT WANTED: Tables A and B + 2 Plots (group A and B) with a short comment each.

->PLEASE REMEMBER: save all videos and files in .trk format (Tracker elaboration) on the PC

¹ Tracker Free Video Analysis Software

Answer sheet

GROUP N° _____

Ch.5 --- QUANTITATIVE RESTITUTION COEFFICIENT

Table A	Ball H			Ball S		
Temperature	h1	h2	CoR (ϵ)	h1	h2	CoR (ϵ)
°C	cm	cm	#	cm	cm	#

Table B	Ball H	Ball S
Temperature	Final Velocity	Final Velocity
°C	m/s	m/s

Comments to Plots:

->PLEASE REMEMBER: save all videos and files in .trk format (Tracker elaboration) on the PC [See general instruction on saving files]

Teachers' Notes

Technical notes:

- This is the second part (more quantitative) of another experiment: see the corresponding file for more details, both theoretical and practical (Ch5_TEACH_EN_Restitution coefficient)

Organizational notes:

- Each student will keep a copy of the students' sheet but the group will collectively fill in the answer sheet and give it over to the teacher in charge at the end of the lab.

Correction grid

Question or Request	Note	Max. score
Tables + Plots	Mark 1 point for each experimental point (data on tables, point in the graph) – Distinguish the two balls	18
Comment		2

Key to Answer

From the plots the different elasticity/speed should be quite evident. The Sad ball is particularly sensitive to Temperature changes

Materials and equipment

- 2 Neoprene and 2 Norboneneballs
- Becher of water
- Hot plate + hot water beaker+ tongs to extract the balls
- Freezer [best would be Liquid Nitrogen] + tongs
- Meter stick
- Ramp
- Smartphone or video camera
- PC with Tracker

MoM resources (<http://www.mattersofmatter.eu/mom-materials/>)

- Ch5_TEACH_EN_Restitution coefficient

References

- <http://polymerambassadors.org/pdf/happyandsad.pdf>
- <https://www.materialsampleshop.com/products/polynorbornene-rubber-offers-excellent-damping-properties>
- <http://galileo.phys.virginia.edu/outreach/8thgradesol/EffectofTemperature.htm>

Where to buy

- Material Sample Shop <https://www.materialsampleshop.com/> 8 € one per couple (H+S balls)



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