Tools for Materials Science - Challenge n°5 - 40’

BOUNCING BALLS

On the desk you have two black rubber balls with H and S painted in white to distinguish them.
Q1. Observe the balls: do you notice any difference?

Q2. Drop them on the desk (be ready to catch them!). Do you notice any difference now? Can you offer any explanation for what you saw?

Q3. Use the weighing scale on the desk and write down the weight of each ball. Is the explanation you gave in Q2 still a good one?

Q4. Put them in the water. Do you notice any difference? Is the density of the two balls different?

Q5. Do you think the bouncing behaviour of the two balls is affected by temperature? If yes, how? Do you think that if you increase the temperature will the balls bounce less or more? They will both bounce less? Or they will both bounce more? Or what else? And what if you decrease the temperature? Write down your prediction with an explanation based on the expected behaviour of the two balls depending on their temperature.

Q6. In order to test your previous prediction, first put the two balls in very hot water for a few minutes and then drop them. What about the bouncing behaviour of the two balls now?
Now ask the teacher for a new couple of H and S which have been stored in the freezer for some time and drop them! What happens now? Fill in the following table with your observations. (*focus on the following fact: is there any bouncing or not? Is the bouncing higher/lower/the same compared to room temperature? Are the bounces of the two balls (if any) the same? If not which one is higher?*)

Bouncing Behaviour	Room temp.		Heated		Cooled	
	Bounce (Y/N)?	Which is higher?	Bounce (Y/N)? Compare to Room Temp.	Which is higher?	Bounce (Y/N)? Compare to Room Temp.	Which is higher?
Ball H						
Ball S						

Q7. Can you give an overall explanation of what you observed ?

Q8. On the desk you also have some Didò (this is a soft modelling paste for kids) and some other “magic stuff”: both materials are plastic ones, you can easily model them: try it! Can you guess what their bouncing behaviour is? Explain your answer.

Q9. Now model them with your hands into two balls and drop them: Both Didò and “magic stuff” are ***plastic***, but only one of them is ***elastic***. Which one? Explain your answer.

Q10. Discuss with your team possible applications of “magic stuff” and write down at least one innovative idea.

☞ **OUTPUT WANTED: answers to Q1 … Q10**

Funded by EU under the Erasmus+ KA2 grant N° 2014-1-IT02-KA201-003604_1

Answer sheet

GROUP N°___________

Ch.5 --- BOUNCING BALLS

Q1

Q2

Q3

Q4

Q5

Q6

Bouncing Behaviour	Room temp.		Heated		Cooled	
	Bounce (Y/N)?	Which is higher?	Bounce (Y/N)? Compare to Room Temp.	Which is higher?	Bounce (Y/N)? Compare to Room Temp.	Which is higher?
Ball H						
Ball S						

Q7

Q8

Q9

Q10

 Funded by EU under the Erasmus+ KA2 grant N° 2014-1-IT02-KA201-003604_1

Teacher’s notes

Technical notes:

- H stands for “happy”; S stands for “sad”: the meaning of these names should be clear from the results of the experiment proposed in Q2.
- **Q1.**If students ask for it, give them something to measure the radius of the ball.
- **Q2.** If you have a thermal camera you can observe some heat trace on the impact site and/or on the ball, but it’s not easy to see something when working with “normal” energies (low energies: height from which the ball is dropped is approx. 1m).
- **Q4.** Difference in density isn’t so big: you can estimate the density of S-ball progressively adding salt to water until the S-ball will float [in this case more time is needed].
- **Q5. – Q7.** A more quantitative analysis of the “bouncing behaviour” can be done by using the “coefficient of restitution”: this will be the subject of another experiment – see the corresponding teacher’s note for further details on this. The definition of “coefficient of restitution” is reported also below.
- **Q8. – Q9.** These experiments are intended to highlight the difference between “plastic” end “elastic”; they can also be performed quantitatively introducing the coefficient of restitution

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
Q1	Only observation	1
Q2	Observation 1 point; Motivation 1 point	2
Q3	Observation 1 point; Motivation 1 point	2
Q4	Only observation (2 point if compared to water)	2
Q5	Only Motivation	2
Q6	See Key to Answer	4
Q7	See Key to Answer; mark point if internal structured is well reported to temperature	2
Q8	Only Motivation	1
Q9	Answer 1 point; Motivation 1 point	2
Q10	Mark point if the idea is well connected to properties	2

Key to Answer

Q1. The two balls look more or less the same: same aspect, same dimension (same weight): so we expect the same behaviour.

Q2. H-ball bounces; S-ball doesn’t bounce at all. We expect from students an explanation based on some different “internal structure” of the ball: S ball has something inside which is heavy (“metallic”); this could be suggested also by the different sound emitted when hitting the table.

Q3. The difference in mass is of the same order of sensibility of the weighing scale, therefore weight is more or less the same: previously given explanations based on “something heavy inside” can’t be correct.

Q4. H-ball has a density which is lower than water density; S-ball has a density higher than water one.

Funded by EU under the Erasmus+ KA2 grant N° 2014-1-IT02-KA201-003604_1

Q5. We expect an explanation based on some change in the stiffness of the balls with temperature: usually colder means stiffer (and more bouncing) and warmer means "softer" ("shapeless") and therefore less bouncing.

Q6. The S-ball bounces in both cases upon heating and cooling; the bouncing is more or less the same. The H-ball still bounces both when cooled or heated, but the bouncing is lower than at room temperature (the effect is more evident for the cooling). When cooled the two balls bounce more or less the same; when heated the H-ball bounces a little more than the S-one.

Q7. See general explanation below.

Q8. – Q9. Usually a material that is very plastic is not expected to bounce at all (or in any case it bounces just a little). But the "magic stuff", in spite of being very plastic, actually bounces a lot (much more than expected !) so it is also very elastic.

Materials and equipment [da rivedere ???]

- 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
- Salt spoon and beacher with water
- Didò + superelastic silly putty

General Explanation

Happy and Sad Balls behave differently in a variety of situations:

- they roll down a ramp at different speeds [like a full (faster) and a half-full can(slower) due to the higher internal friction of the second)]
- they emit sound waves at different decibels (sad ball emits a characteristic "thud" like a stone or a metal clump)
- they bounce different heights on the same surface
- they are differently affected by temperature
- they can be compressed in dissimilar amounts when the same force is applied
- they have different densities, so they sink in different solutions at variable rates.

The Sad Ball has different characteristics. When it is dropped from the same height onto the same surface, it does not bounce even though it has been given the same amount of potential energy as the Happy Ball. It's a totally inelastic collision.

This is because the two balls are made up of different materials. The Happy Ball is made of Neoprene (common rubber), the Sad Ball is made of Norbonene, also called Norsorex commercially. On a molecular level, Norbonene is different from Neoprene because Norbonene's polymers are more loosely arranged and rub together more when the ball deforms[1](→ more internal friction, therefore the analogy with a half filled can). This additional movement results in motion being converted to heat energy: instead of the ball bouncing, it gets warm.One way to change the bounciness is <u>changing the temperature</u> of the ball. When the Happy Ball is cooled, its molecules are not as flexible, causing the ball to rebound a smaller distance. When the Sad Ball is

[1]Polynorbornene rubber compounds (rubber mixed with different additives) offers excellent shock absorption and damping properties (aka high hysteresis). The rubber can be mixed with a large volume of plasticiser, compared with other types of rubbers, to achieve a very low hardness. From https://www.materialsampleshop.com/collections/polymer/products/polynorbornene-rubber-offers-excellent-damping-properties
Polynorbornene is used mainly in the rubber industry for anti-vibration, anti-impact and grip improvement .

Funded by EU under the Erasmus+ KA2 grant N° 2014-1-IT02-KA201-003604_1

cooled or even heated the Norbonene polymer does not deform as much, so less energy is converted to heat energy and the ball bounces in both cases.

Polymers such as elastomers show the so called glass transition temperature, that is temperature at which the material changes from a hard, glassy crystalline material to a soft, rubbery, amorphous material. The two balls have different glass transition temperatures (H: -42°C; S: 35°C) therefore they bounce differently.
This also accounts for the fact that at the temperatures you are able to manage in a school lab, the S ball will undergoes the most dramatic changes, while the other one will not differ too much.

The densities of the balls will vary slightly so it's not really easy to distinguish them. However Norsorex is a little denser than water. On alternative is to add water to raise the density till both balls will float. The density is approx. 1.216 -1.115 g/mL (S) and 1,166 -1,097 g/mL(H).

Note: Coefficient of Restitution -The bounciness of an object/material is measured through the so called "coefficient of restitution". It is a number *e* with 0 ≤ *e* ≤ 1. It is an index of how much elastic is the bounce (e=0: totally inelastic; *e*=1 totally elastic) and can be calculated with the ratio of the two speeds (incoming just before the bounce, outcoming just after the bounce).Actually the coefficient is calculated as the ratio squared of the final height h reached after the first bounce and the dropping height H: this method is equivalent to the previous one ONLY if the bounce is exactly vertical: using Max. Potential Energy = Kinetic Energy at h= 0 we have: $Coeff.of\ Rest. = e = \frac{\sqrt{2gh}}{\sqrt{2gH}} = \sqrt{h/H}$ (ratio of potential energy before the drop and after the first bounce at the maximum height reached)

MoM Resources (http://www.mattersofmatter.eu/mom-materials/)

- **Ch5_TEACH_EN_Quantitative Restitution coefficient** this activity becomes more quantitative as the two bas motion it analysed with Tracker Video Analysis software. It's an excellent complement to the activity of this sheet.

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)

Erasmus+

"The European Commission support for the production of this publication does not constitute an endorsement of the contents which reflects the views only of the authors, and the Commission cannot be held responsible for any use which may be made of the information contained therein.

Funded by EU under the Erasmus+ KA2 grant N° 2014-1-IT02-KA201-003604_1

 Funded by EU under the Erasmus+ KA2 grant N° 2014-1-IT02-KA201-003604_1