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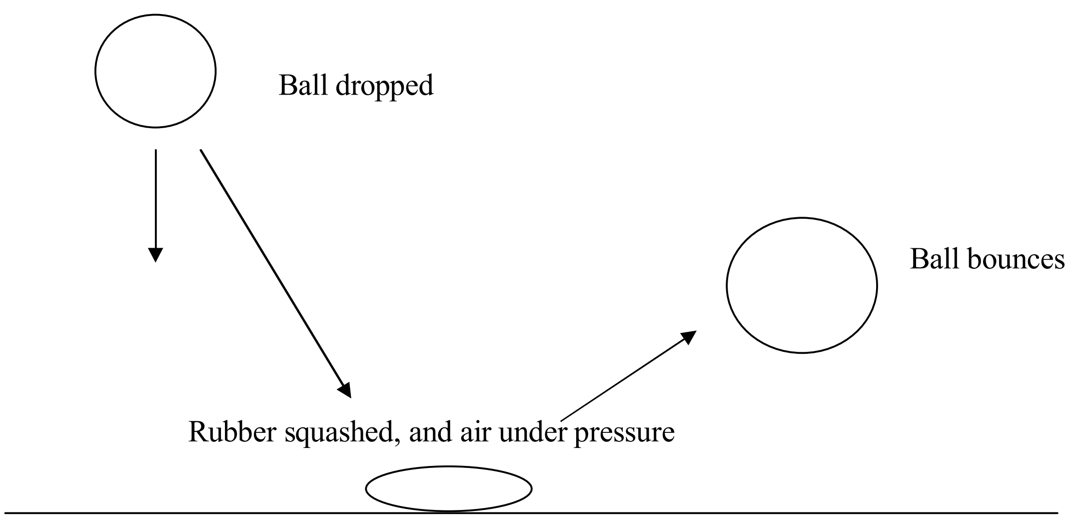
# Physics Coursework: *the bounciness of a squash ball over a range of temperatures*

**Introduction**
I plan to investigate the bounciness of a squash ball and the effect certain factor have on it.

**Factors affecting the bounciness of a squash ball**
Temperature
Atmospheric Pressure
The type of squash ball
The surface it is bouncing on

I intend to investigate a continuous variable, and of these factors, only two are continuous. However, it would be much simpler to investigate the effect of temperature than to conduct the experiment in some sort of pressure chamber. Therefore, I will investigate the effect that temperature has on the bounciness of a squash ball. If I am investigating this variable, all the others must remain constant throughout the experiment in order to make it a fair test. This will be relatively easy as long as I keep the surface it is being bounced on clean, and make sure that the squash ball does not become punctured. Atmospheric pressure should remain constant.
A squash ball bounces because of several different factors. The first of this is that it is made of rubber, which is very elastic, so when the ball is dropped, the rubber compacts, and then expands again. This means that when a rubber object is dropped from a height, gravitational energy is converted into kinetic energy as the ball is falling. When the ball hits the ground, the rubber compacts, and kinetic energy is converted into elastic. Then as the rubber expands, the elastic energy is converted back into kinetic, which then goes to gravitational potential. The other reason for the bounciness of a squash ball is that it is filled with air. This means that when the rubber is compacting and expanding, the air inside comes under pressure, so also compacts and expands. This bouncing is illustrated below:



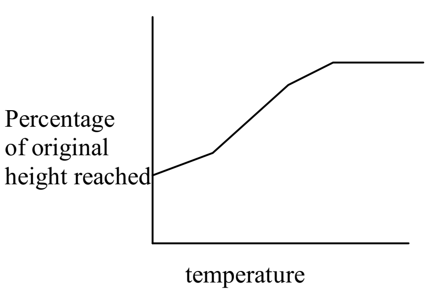

This process is not one hundred percent efficient, this is because of each of the conversion processes are inefficient; as the ball falls, there is air resistance, but this has very little effect over the distances involved, but the main inefficiency of the bouncing process is when the rubber hits the ground. This is because of the properties of rubber; it is made up of many macromolecules, which are held together with fairly weak van de Waal's forces, although modern rubber is mostly vulcanised. This means that the molecules are joined with much stronger sulphur linkages.

However, the principle is the same, which is that when the ball bounces, and the rubber contracts, the molecules slide over each other, and then back again as the rubber expands. But when the molecules are sliding over each other some of the energy is turned into heat. The air also goes through a similar process, it comes under pressure, so gets squashed, then expands again. But the big difference between the air and the rubber, is that the air is much more efficient, as not much energy is lost as heat.

Therefore, when a squash ball is heated up, the heat has a double effect; the rubber becomes softer, as the van de Waal's attractions are partially overcome, so the molecules can slide past each other more easily, so there is less heat lost when the rubber contracts and expands. And the air expands, so is at a higher pressure, so would play a greater part in the bouncing process, as the rubber would have to deform less, before the air comes under enough pressure to make it bounce back, and the less the rubber has to move, the more efficient the bouncing would be.

**Hypothesis**

I think that as the squash ball is heated more, it would bounce to a greater percentage of the height from which it was dropped. This trend could clearly not go on forever, on because that would mean that at high temperatures, the ball would bounce more than 100% which is impossible. However, with such a complicated subject as the squash ball, I do not think that I could possibly make a quantitative prediction relating the temperature and the percentage bouncing efficiency. This is partly due to the fact that I will be measuring the temperature in degrees, and air pressure is not proportional to degrees Celsius, only Kelvin. I also do not know enough about the inner workings of rubber to know if it will get proportionally softer with the heat. Therefore, my hypothesis is that as the temperature increases, the percentage efficiency of the bouncing process will increase. This will then curve off towards the top of the graph, (and then suddenly decrease to close to zero, if the rubber was heated until it melted). I also would like to suggest that the graph showing percentage efficiency against temperature would change its gradient at a certain point. This would be because at low temperatures, the ball would bounce using only the elasticity of the rubber, when the air was at a very low pressure. In other words, the rubber was so hard, and the air was at such a low pressure, that there might as well have been a hole in the ball, because the increased air pressure during the bounce was having no effect. Then, when the ball gets to a certain temperature, the air pressure will get high enough, that it will begin to have an effect on the bouncing of the ball. This is because, as the ball compacts, the high air pressure would stop the rubber from squashing as much as it would otherwise. This effect would increase, so the efficiency would increase. Therefore, I think that my graph showing the percentage efficiency against the temperature would look like this:




**Plan**

In order to conduct such an experiment, I will have to find an effective way of heating, and cooling a squash ball, clearly, I could not just hold it in the flame of a Bunsen burner. Therefore, I came up with the idea of putting the squash ball in a beaker of water, and heating this in a flame. This would mean that the whole ball would be evenly warmed, and I would be able to accurately measure the temperature. The next problem I encountered in planning my experiment was how to measure the height to which the ball bounced accurately. I considered some sort of pressure switch, which

would time the gap between the first and second bounces, but was restricted by a lack of equipment, and decided it would be easier to just ask someone else to drop the b all, next to a metre rule, while I recorded how far the ball bounced.
I was worried that it would be hard to keep the ball at a constant temperature, while I was conducting the bounces. This is because I will repeat each reading several times, so the ball would cool between each one. Therefore, I decided, that I would take one reading, then replace the ball in the water, which would be at the required temperature. This would also have the added advantage of making sure that the temperature was exactly correct for each reading, where otherwise I may be out by a few degrees. I decide that the appropriate time for which the ball should be left in the water was thirty seconds.
Another potential cause for error is that I might heat the water too fast, and as the thermometer would only record the temperature of the water, the ball may not have got to that temperature yet. Therefore, I must make sure that the ball is heated very slowly and carefully so that all of it would always be at the same temperature as the water.

**Method**

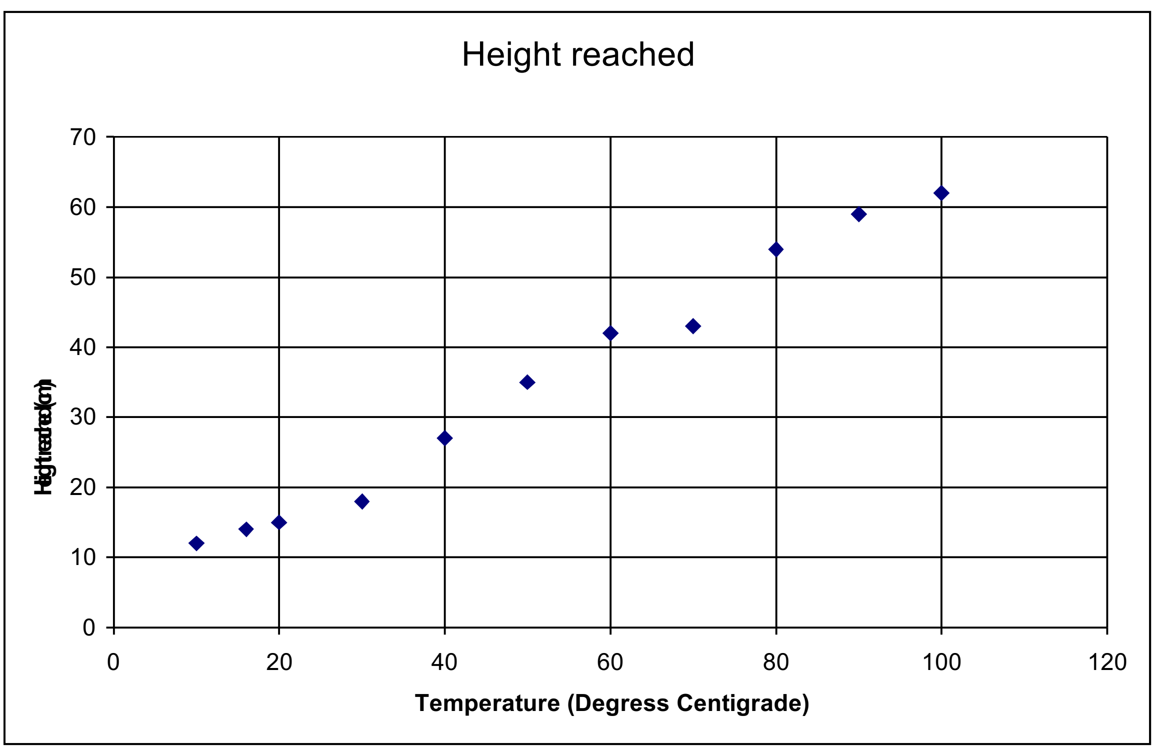
*Throughout this experiment, you must be careful of hot apparatus, and be careful not to break any glass. If you do, inform the master in charge immediately.*

1. Set up the metre rule vertically. Put some water in the beaker.
2. Place the squash ball in the water, and add a little ice while stirring the water.
3. When the water reaches 10$^{o}$C, take the ball out of the water and dry it. Then get someone else to drop it from 1m, while you record how high the ball bounced. Replace the ball in the water, leave it there for thirty seconds (to maintain the water at 10 degrees you will have to skilfully add or remove ice, as appropriate). Then take the ball out again, and repeat the process of taking the readings.
4. When you have taken three readings for that temperature, take the ice out, and slowly warm the water to 20 degrees in the Bunsen burner flame. Leave it at 20 for thirty seconds, then take the ball out and take a reading. Repeat the process above, so that you have three readings for each temperature.
5. Again, slowly heat the water to 30$^{o}$C in the way stated above, and take three readings at that temperature
6. Take readings at every 10$^{o}$C interval up to 100 degrees, taking great care of the hot water, and the hot squash ball. You may need to hold the ball in a tissue, or ask the teacher for assistance.

7. Once you have taken three readings for each temperature, leave the water, the ball and the hot apparatus such as the tripod to cool off. Ensure that the Bunsen burner is properly switched off. Then replace all the equipment.
8. Throughout the experiment, you must make sure that the surface that the ball is bounced on is always the same. Check that no water is left on the surface as this could alter the results, and the ball must always be dry. You must also move the ball from the water, and bounce it as quickly as possible, so that it does not cool too much before it is bounced. For some of the higher temperatures, you may want to heat the water to a couple of degrees above the necessary temperature so that it is at the correct temperature when it is bounced.
9. When you have a set of results, take the average of the three readings, and construct a graph showing the average height reached for that temperature, plotted against the temperature. If my hypothesis was correct, the graph should look like the sketch above.

**Results**

| Temperature/$^{o}$C | Reading 1 | 2 | 3 | Average |
|---|---|---|---|---|
| 10 | 11 | 13 | 12 | 12 |
| 16 | 13 | 14 | 15 | 14 |
| 20 | 16 | 15 | 15 | 15 |
| 30 | 18 | 18 | 19 | 18 |
| 40 | 26 | 27 | 29 | 27 |
| 50 | 35 | 34 | 35 | 35 |
| 60 | 41 | 44 | 40 | 42 |
| 70 | 47 | 48 | 34 | 43 48 |
| 80 | 56 | 54 | 52 | 54 |
| 90 | 59 | 60 | 59 | 59 |
| 100 | 63 | 63 | 60 | 62 |



**Conclusion**
This graph does seem to have the kink in it that I predicted, and there is some sign of it beginning to tail off when it reaches 100°C. I think that this graph definitely backs up my hypothesis, as it shows that there is a distinct change in the angle of the line at around 30°C, which I can directly attribute to the rubber having softened sufficiently, and the air pressure has increased enough for the air pressure to stop the ball from squashing as much as it otherwise would. There is also a slightly less distinctive tailing off of the graph at the other end of the scale, although this is only one point, so I cannot be sure that it is not experimental error. Therefore, my hypothesis was correct, and the bouncing of a squash ball is affected primarily by the rubber, which is elastic, so bounces, and then, when it gets to a high enough temperature, the air inside the ball gets to a high enough pressure to prevent the rubber from completely flattening, so plays a part in the bouncing process. The air is much more efficient at bouncing, so that is why the graph rose more steeply when the air began to become involved in the bouncing process.

**Evaluation**
I think that overall I was fairly accurate in taking my results; each point plotted on the graph was the average of three readings; I made sure the ball was at close to the exact temperature for each reading. However, one of my readings was clearly out, and very different from the others. This has meant that the average height at that temperature defies the trend of the graph. I have highlighted the reading that was clearly wrong, and calculated the average of the other two points for that temperature. I then plotted this second average onto the graph, and this fits much better to the trend of the graph. This may have arisen from an odd bounce, or I could have recorded the data wrongly. Thankfully, I spotted this now, so that my graph is now more accurate.
If I was to conduct this experiment again, I would collect another set of data with the same squash ball, but this time it would have a small hole drilled in the side, so that I would be able to test my theory that the bounce is only being affected by the elasticity of the rubber, until the air gets to a certain pressure. Thus, I would get another graph, which I predict would be very similar to my original one, until it gets to around 30°C, when my original graph would rise sharply, but the one with a hole in would continue at the same gradient. I also might like to investigate the influence of height on the ball. This would mean that I could see the effect of the ball bouncing at a higher velocity. This would mean that there would be a greater squashing of the ball, so perhaps the effects of the air pressure would have an influence at a lower temperature.