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Measuring Inelasticity

AP Physics C – Mechanics

Objective

You will be working with a few systems in order to quantify the inelasticity of collisions. Most collisions in the real world are inelastic (but not perfectly so). Therefore, it is important to gain an understanding of them.

Pre-lab Questions

1. What is an inelastic collision? Describe it in words, and also state which quantities are/are not conserved, if there are no external forces.
   An inelastic collision represents most collisions in the real world. It is a collision where kinetic energy is lost while momentum is still conserved. The overall kinetic energy is partially transformed into other forms of energy.
2. What is the name of the coefficient that measures elasticity? List the formula below.
   Coefficient of restitution.
   $$C = \left|\frac{v_2 - v_1}{u_2 - u_1}\right|$$
3. Would air resistance be negligible for a falling tennis ball in a classroom? If so, what does the formula from Question 2 simplify to for a collision between the ball and the ground, if the tennis ball bounces to a height *h* after starting at an initial height *H* and traveling to the ground?
   Yes, air resistance would be negligible for a falling tennis ball in a classroom because the ball doesn't come close to reaching terminal velocity due to the low drop height.

   If it was negligible, then the coefficient would simplify to $\left|\frac{v_2}{u_2}\right|$ because u_1 and v_1 (assuming these are earths velocity) would be roughly the same in each scenario since the force the ball applies would barely change the momentum relative to its previous momentum. We know $\frac{1}{2}v_2^2 = gh$ and $\frac{1}{2}u_2^2 = gH$, (by conservation of energy) so it would simplify to $\sqrt{\frac{h}{H}}$
4. Where can the kinetic energy go during inelastic collisions?
   Friction causes some of the kinetic energy to transform to thermal energy. Energy from sound may also be lost during the collision. It can sometimes be transformed into forms of potential energy, such as elastic (spring) or chemical.

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Materials

- Meter sticks
- Tennis balls
- Projectile launchers
- Stopwatches/phones
- Dynamics cars
- Motion detectors
- Force sensors
- Aluminum foil
- Tape
- String
- Ring stands
- Anything else you need

Procedural Requirements

One of the experiments is to quantify the elasticity for a bouncing tennis ball, using the formula you derived above. Do 2-3 trials for one constant drop height. Aside from that, you may utilize some or all of the materials above, to determine the elasticity for two more situations with collisions. Show how you derived formulas for or calculated the coefficients for inelasticity and explain why they are or are not expected.

Tennis Ball drop

Trial	Height dropped	Height returned	Pre-collision speed	Post-collision speed	Coefficient of Restitution
1	1m	.57 m	4.427 m/s	1.0677 m/s	0.7550
2	1m	.56 m	4.427 m/s	1.0583 m/s	0.7483
3	1m	.56 m	4.427 m/s	1.0583 m/s	0.7483

$$\frac{1}{2}mu_2^2 = mgH$$

$$u_2 = \sqrt{2gH}$$

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$$\frac{1}{2}mv_2^2 = mgh$$

$$v_2 = \sqrt{2gh}$$

Plug in value above to solve

$$C = \left|\frac{v_2 - v_1}{u_2 - u_1}\right|$$

Ping pong ball drop

Trial	Height dropped	Height returned	Pre-collision speed	Post-collision speed	Coefficient of Restitution
1	1m	.53 m	4.427 m/s	1.0296 m/s	0.728
2	1m	.54 m	4.427 m/s	1.0392 m/s	0.735
3	1m	.54 m	4.427 m/s	1.0392 m/s	0.735

$$\frac{1}{2}mu_2^2 = mgH$$

$$u_2 = \sqrt{2gH}$$

$$\frac{1}{2}mv_2^2 = mgh$$

$$v_2 = \sqrt{2gh}$$

Plug in value above to solve

$$C = \left|\frac{v_2}{u_2}\right|$$

Block Crash

Trial	Block 1 Initial Velocity	Block 2 Initial Velocity	Block 1 Final Velocity	Block 2 Final Velocity	Coefficient of Restitution
1	.438 m/s^2	-0.568 m/s^2	-.469 m/s	0.290 m/s	0.7544

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$$C = \left|\frac{v_2 - v_1}{u_2 - u_1}\right|$$

Plug in the values above.

Describe your experiments here.

The first experiment was a ball drop (tennis ball and ping pong ball), where the initial height the ball was dropped was kept constant and the height that the ball returned was measured and recorded. The other experiment had to do with the collision of two cars on a ramp where one had a spring attached to the end. The two cars were flung towards each other, and the initial and final velocities of each were measured using a motion sensor and the Capstone software.

Results and Discussion

Analyze your systems by characterizing the elasticity of the collision for each situation. Include data and calculations, as well as assumptions for each situation (did you assume conservation of something? Any neglected forces?). For the tennis ball case, does the coefficient characterizing elasticity vary with dropped height for the ball? Also discuss sources of error in the lab and how they may have affected your results.

The first experiment we did was a ball drop. The height was kept constant, and the height returned was measured. After, the formulas $u_2 = \sqrt{2gH}$ and $v_2 = \sqrt{2gh}$ were used to calculate the velocities of the ball before and after the collision, and $C = \left|\frac{v_2}{u_2}\right|$ to find the coefficient of restitution. Here, the coefficient of restitution varies with the height the ball was dropped, because the ratio of the velocities is the same as the square root of the ratio of the ending and starting heights. It was found to be .7505, on average, which characterizes the collision as an inelastic collision. This is reasonable since some energy should be lost since balls are not super bouncy and heat/sound energy is lost on collision. The same procedure was followed for the second experiment except with a ping pong ball. The coefficient of restitution was found to be 0.234, which characterizes the collision as inelastic as well. This is reasonable since ping pong balls aren't very bouncy and loose energy to thermal/sound on collision. The final experiment was where two cars on a ramp with a spring attached to the end were flung towards each other. The initial velocities of each were measured, and the final velocity of each were measured. The coefficient of restitution was calculated to be 0.7544, which makes the collision inelastic. This is reasonable, since it should be closer to 1 since the end is springy but shouldn't be that close since it is not necessarily a perfect spring that returns all energy and the real-world loose energy. In all the experiments, we assumed conservation of momentum, and air resistance is neglected for calculations because the effect of air resistance is minimal in this experiment.

Possible sources of error include air resistance on the ball and ping-pong ball drop. This would lead to the balls losing energy which would skew the calculations of initial and final velocities (since we relate them to height). Another possible source of error includes friction when the carts collided. This could be avoided by using tracks with less friction. Another possible error was human measurement on the ball drop since the time interval short. This could be prevented by more trials or dropping from a higher height to bring the time to a larger scale to reduce error.

Post-lab Questions

1. Based on your data, can the coefficient that characterizes elasticity be any number between 0 and 1? How does this compare with your expectations? Use what you know about the different types of collisions to justify your answer.
   Yes, it can be. This matches our expectations as collisions can range in their loss of kinetic energy. A perfectly inelastic collision has a coefficient of 0, while a perfectly elastic collision has a coefficient of 1. Any collision with a coefficient between 0 and 1 loses some energy, but not as much as a perfectly inelastic collision.
2. Are there any values of the coefficient that are predicted by the theory but not realizable in a laboratory setting? Which one(s)?
   Large values of the coefficient above 1 (some higher values were possible but not very high ones) and perfectly 1, as real life prevents perfectly elastic collisions just due to friction and sound.
3. How could the elasticity of collisions be changed to ensure safety to the objects' state before collisions (for example, if you throw an egg at a wall, what could you change to prevent cracking/splattering of the egg?)?
   Elasticity is proportional to the impulse acted on both objects of a collision, so a lower elasticity would lower the impulse and therefore be safer for both objects. If the collision was perfectly inelastic, the objects would be most unlikely to break apart as they would be stuck together after the collision with the greatest possible amount of kinetic energy removed from the system (least possible impulse acted on the objects).
4. Why might it be important to know elasticity of collisions in the real world?
   To predict the results of collisions and properly understand the resulting velocities and kinetic energies after a collision. These results allow for better simulations which can lead to safer environments. Elasticity can also be used to determine how fast cars were going before an accident, which shows people which ways to be more careful when driving.