Inertia Experiments and Demonstrations

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the science reflector
SUMMER 2004
VOLUME 33, NUMBER 2

Inertia is the natural tendency of an object to maintain state of rest or to remain in uniform motion in a straight line. It is the fundamental property of matter where an object opposes being accelerated or decelerated. Newton related concept of inertia to mass. Initially, he called mass a quantity of matter, but later redefined it as the measure of inertia. A more massive object has more inertia i.e., more resistance to any change in its state of motion than a less massive object.

Newton's First Law of motion also known as Law of Inertia states that an object will remain at rest or in a uniform motion along a straight line unless it is acted on by an external net force. This means that an object at rest will stay at rest until a force causes it to move. At the same time, an object in motion will stay in motion until a force acts on it and causes its velocity to change in magnitude and/or direction.

The concept of inertia was first introduced by Galileo, a leading 17th century scientist (1). He reasoned that a moving object is eventually forced to stop by friction and other dissipative forces. In experiments using a pair of inclined planes facing each other, he observed that a ball would roll down one plane and up the opposite plane to approximately same height. If smoother planes were used, the ball would roll up the opposite plane even closer to the original height. Galileo reasoned any difference between initial and final heights was due to the friction. He postulated if friction could be entirely eliminated, then the ball would reach exactly the same height. This concept was, however, opposite of the popular notion that the Greek philosophers and others held for nearly 2000 years. The accepted opinion was that all moving objects would stop because the natural state of objects was to be at 'rest'. This appeared logical, based on our own observations (e.g., tops that stop spinning and wheels that stop turning).

There is an on-going research that looks deeper into the origin of inertia. Dennis Sciama in1953 (2) showed that gravity could account for inertial reaction forces. According to California Institute for Physics and Astrophysics (3), property of inertia has not been addressed properly by quantum field theory or superstring theory. The institute is involved in exploring if stochastic electrodynamics (SED)-based inertia hypothesis can be validated and generalized within the comprehensive discipline of modern quantum field theory and superstring theory. An accelerating object induces asymmetry resulting in zero point field (ZPF) fluctuations (SED-based hypothesis) or quantum field distortions (Quantum Vacuum based inertia hypothesis). These fluctuations make the accelerating objects experience a drag force displaying the property of inertia. Acceleration of the objects could be due to change in speed or direction or both in relation to time.

It was proposed by Haisch, Reuda, and Puthoff (4) that the inertial mass of an object can be traced back to the energy density of electromagnetic zero-point field (ZPF) instantaneously transiting through and interacting with the object. Inertia of matter could be interpreted at least in part as a reaction force originating in interactions between the ZPF and the elementary charged constituents (quarks and electrons) of matter. Within the limited context of that analysis, it appeared that Newton's equation of motion, $F = m\,a$, could be inferred from Maxwell's equations as applied to the ZPF, i.e. SED version of the quantum vacuum. Some researchers take a new approach in which a non-zero ZPF momentum flux arises naturally in accelerating coordinate frames from the standard relativistic transformations of electromagnetic fields. Scattering of this ZPF momentum flux by an object will yield a reaction force that may be interpreted as a contribution to the object's inertia.

We see many examples of matter displaying the property of inertia in our daily routine. These examples include being pushed backward when a car/vehicle takes off or pushed forward when it stops (sudden taking off or stopping makes the effect more pronounced) or more massive object requiring more effort to stop its motion or to set it in motion as compared to a less massive object. One has seen a waiter removing the tablecloth fast underneath the dishes without letting dishes fall down from the table. This behavior of matter is like the nature of an old person who resists change, especially, if the change is fast and sudden. Here is a compilation of some experiments displaying matter's property of inertia for middle and high schools. Most of these experiments can be done without much difficulty in the lab/classroom, whereas some would need practice and precaution. Comparable pieces of equipment, apparatus, or material can be substituted depending on availability. The authors would be glad to give these demonstrations depending on schedule and distance.

1. Wooden Hoop/Ring and Pen Cap

Equipment/Apparatus/Material: Wooden hoop or ring 8-10 inches diameter (available in sowing sections of department and other stores), 250-ml Erlenmeyer flask, pen cap

Procedure: Balance the hoop in the center of the mouth flask and then balance the pen cap on the hoop aligning it with center of the flask mouth (hole). Pull the hoop fast forward or backward, and if done correctly the cap would fall straight into the flask. Since the cap is just sitting on the hoop, it shows resistance to sideways motion when the hoop is pulled. However, having no place to stay and it falls straight down under influence of gravity. The demonstration can also be done using glass soda bottle.

2. Eggs in Water

Equipment/Apparatus/Materials: 3 wide mouth glass/metal tumblers 12-14 oz capacity, 3 ABC wood toy blocks, 3 eggs, water, flat metal plate 17-18 inches diameter, broom

Procedure: Place the glass/metal containers at a table and fill them with water. Cover the containers with flat metal plate. Put the ABC wood blocks (with side facing up where an egg can rest without rolling down) on the plate each above the water containers about in the center of their mouths. Place one egg on each support. Hit the metal plate with broom handle carefully on the side hard to make it fly away. Broom side held on the floor under foot and releasing handle at an angle to hit the board would provide a better impact. As the board flies away the eggs would fall in water. If not done correctly the glass tumblers may get hit and break. It is advisable to wash your hands after handling raw eggs. To avoid mess, boiled eggs might work better. Please do not use living room for this.
As the metal plate is hit, the eggs just resting above it resist horizontal motion and fall down under the influence of gravity.

3. Boiled and Raw Eggs

Equipment/Apparatus/Materials: Hard boiled egg, raw egg

Procedure: Spin the eggs, one at a time, on the side on a smooth hard surface, stop them fast and let them go immediately. The boiled egg will spin easily to begin with but will not spin any more after stopped suddenly and released. However, the raw egg will spin again after quick stopping and releasing it because the liquid inside the raw egg is still in motion due to inertia. Please wash your hands when handing raw eggs. This technique can be used to find out if the egg is raw or boiled.

4. Inertia of Air Molecules

Equipment/Apparatus/Materials: 10-12 inch long, 1 inch wide, and 1 inch thick wooden stake, 16 inch by 16-17 inch sheet of paper (two legal sheets of paper can be taped together, or a newspaper sheet), table

Procedure: Spread the sheet of paper on the table aligning its edge with the edge of the table. Insert and center the stake under the paper with less than half protruding out from the paper/table edge. Hit the stake fast with hand (like karate chop) closest to the table without hitting tabletop. The stake will break if done correctly. Do not touch the paper when stake is being hit. The paper surface is carrying an air pressure of 15 psi and when stake is hit, it tries to accelerate the air above the paper surface which offers resistance enough to cause the stake to break.

The students should be moved a little far from the activity as the shattering wooden pieces can hit somebody and might cause injury.

5. Flat Bottom Flask

Equipment/Apparatus/Materials: Erlenmeyer glass flask, smooth sheet of paper, and flat tabletop surface

Procedure: Lay the paper sheet on the flat table surface and set the flask in the middle of the paper. Hold the paper on the side and move it slowly. Both paper and flask would move. Move the paper fast, the paper would slide off leaving the flask behind. When the paper is moved suddenly, flask's resistance to change in state of motion is distinctly is visible. It is the same technique used in moving tablecloth underneath the dishes.

6. Heap of Coins

Equipment/Apparatus/Materials: Quarters, metallic spatula.

Procedure: Stack quarter coins one above the other on a flat surface. Hit one of the bottom coins with the edge of the spatula. That quarter will come out and the others in the stack will slide down. The coins can be removed one at a time. Since coins are just sitting one above the other and when one of them is hit sideways, the ones in immediate vicinity resist that motion and the stack slide down under effect of gravity.

7. Wooden Bed with Nails

Equipment/Apparatus/Materials: Two specially constructed wooden frames 3 ft by 1 ft with 2-inch nails protruding through the wooden bottom with all the nails very precisely machined to give a extremely leveled surface (the nails making a grid with one and a half to two inches space between them), hollow brick, sledge hammer, volunteer, safety goggles

Procedure: Ask the volunteer to lie on back on nail side of one of the wooden frames and put the other frame on his chest with nails pointing downwards. The volunteer should put on goggles. Put the brick on the frame. Hit the brick with hammer and hollow brick should break under the impact without hurting the volunteer if done correctly. Because of the resistance offered by the heavy wooden frame, the impact does not affect the volunteer.
This experiment has inherent risks and needs a lot of practice and precautions. It should not be done without extreme caution and skill.

8. Nail Pounding on the Head

Equipment/Apparatus/Materials: 3-4 thick books, small wooden board, nail, hammer, volunteer, brick

Procedure: Place 3-4 thick books on the head of a volunteer. Place the wooden board on top of books. A hammer is used to drive the nail into he board. Due to the large mass of the books, the force of the hammer is sufficiently resisted (inertia). This is demonstrated by the fact that the hammer blow is not felt by the volunteer. A common variation of this demonstration involves breaking a brick over person's hand using swift blow of the hammer. The massive brick resists the force and the hand is not hurt. Caution should be exercised with this experiment.

9. Big and Small Masses

Equipment/Apparatus/Materials: 6-7 kg round or square mass with hooks on opposite ends, 0.5-0.6 kg round or square mass with hook on one side, string (just strong enough to support the heavy mass), stand

Procedure: Place the stand at raised level. Suspend the large mass from the stand using about 2 feet long string leaving about one foot space between the mass bottom and the floor. Make sure that stand and the hanging mass are stable and can withstand pulling of mass with a slight jerking action. Hang the smaller mass with 2-3 inch string from the bottom hook of the bigger mass. Pull down the smaller mass with a slight jerking action. The smaller mass would come off without affecting the bigger mass. The larger mass offers resistance when smaller mass is pulled abruptly. It is an action similar to when paper towel or tissue paper is pulled out from a bigger roll with a fast jerking action.

10. Square/Round Peg and Wooden Block

Equipment/Apparatus/Material: 10-12 inch long square or round wooden peg, wooden block (more massive than the peg) with a hole just big enough for peg end to fit snugly, hammer

Procedure: Lightly insert peg end into the block hole. Hold the peg and block assembly in hand and tap the open end with hammer. With each tap the peg will move further into the hole of the block. The block does not have to be held against any hard surface. Because of the mass of the block it resists motion when the peg is tapped down.

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Photos courtesy of the NC State Physics Demo Room http://demoroom.physics.ncsu.edu/

The Science Reflector
Newsletter of the North Carolina Science Teachers Association
PO Box 1783, Salisbury, NC 28145
Elizabeth Snoke, Editor