Dropping things!
Does Newton's 3rd Law of motion apply?

Grade(s): Middle School
Topic: Physical Science

Standards:

Disciplinary Core Ideas: MS- PS2 Motion and Stability: Forces and Interactions

- For any pair of interacting objects, the force exerted by the first object on the second object is equal in strength to the force that the second object exerts on the first, but in the opposite direction (Newton's third law). (MS-PS2-1)
- The motion of an object is determined by the sum of the forces acting on it; if the total force on the object is not zero, its motion will change. The greater the mass of the object, the greater the force needed to achieve the same change in motion. For any given object, a larger force causes a larger change in motion. (MS-PS2-2)
- All positions of objects and the directions of forces and motions must be described in an arbitrarily chosen reference frame and arbitrarily chosen units of size. In order to share information with other people, these choices must also be shared. (MS-PS2-2)

Science and Engineering Practices:
1. Asking Questions and defining problems
2. Developing and using models
3. Planning and Carrying out Investigations
4. Constructing Explanations and Designing Solutions
5. Obtaining, evaluating, and communicating information

Anchoring Phenomenon:
Show teachers the quarter and 3 pieces of paper.
What will happen if a quarter with a small piece of paper is dropped on top of it or underneath it?
Most of the time the following will occur:
The coin and paper of the same size or smaller than the coin fall together regardless of the order.
The coin and paper that is larger than the coin will fly off the coin and will fall and take more time to reach the floor than the coin.

Materials: Per group
2 meter sticks or 2 meters in measuring tape
10-Coffee filters
10 pennies
Stop watch or phone timer
Tape
Paper

Advanced Preparation:
Precut coin size paper for anchoring phenomenon.
Collect materials that students might use for investigating.

Make a list of questions about the quarter drop activity.
What are some ways we can investigate the phenomenon?
Let's explore what's happening?
What evidence can you provide?

Underlying Science:
When the piece of paper (smaller than the coin or the same size as the coin) are placed on top of the coin and dropped, the two act as one and the fall together at the rate the coin is falling.
If, however, the paper is larger than the coin, the paper encounters air resistance and flies off the coin and feathers through the air at a slower rate than the coin.

As an object falls through air, it usually encounters some degree of air resistance. Air resistance is the result of collisions of the **object's leading surface with air molecules**. The actual amount of air resistance encountered by the object is dependent upon a variety of factors; its speed, its cross-sectional area, its shape and the density of the air.

As an object falls, it picks up speed. The increase in speed leads to an increase in the amount of air resistance. Eventually, the force of air resistance becomes large enough to balance the force of gravity. At this instant in time, the net force is 0; the object will stop accelerating. The object is said to have reached a **terminal velocity**. The change in velocity terminates as a result of the balance of forces.

Objects that are said to be undergoing free **fall**, are not encountering a significant force of air resistance; they are **falling** under the sole influence of gravity. Under such conditions, **all objects** will **fall** with the **same rate** of acceleration, regardless of their mass.

Coin and paper drop
Gravity pulls equally on all objects, the light paper and the heavier coin both fall at the same rate or (accelerate). Gravity causes the speed of falling objects to increase at a rate of (9.8 ms^2 or 10 ms^2).

Coffee filter activity

The heavier filter with the same area as a lighter one must fall faster to reach terminal velocity. So more massive filter stacks have a higher terminal velocity and fall further in the same time.

Penny and Penny stack drop
The single penny and the stack of pennies would require a farther distance to fall for each to reach terminal velocity. (approx.50 feet for the single penny)

Easy to remember statements about dropping things!
Gravity force is proportional to the mass.
No net force means no acceleration.
Air resistance also increases as the speed increases, for coffee filters the air resistance force is proportional to the square of the speed of fall.

How could you investigate that objects fall at the same rate?
How would you teach the idea that all objects fall at the same rate?

Fun facts:
Average Human – 120mph after falling 1500 ft. (192 km/hr.)
Penny – 30-50 mph after falling 50 ft.
Ant -6.4km/hr. or 3.4 mph
Ping pong ball – 20ish mph
Rain drop – 15mph
Baseball – 100ish mph

Historical background:
Aristotle taught: that heavy objects fall faster than lighter ones, in direct proportion to their weight. Galileo, believed that all objects fall at the same rate regardless of their mass. It is believed that he never actually did this experiment at the Leaning Tower of Pisa, but only wrote about it as a thought experiment.
Astronaut David Scott performed a version of the experiment on the Moon during the Apollo 15 mission in 1971, dropping a feather and a hammer from his hands. Because of the negligible lunar atmosphere, there was no drag on the feather, which hit the ground at the same time as the hammer.

LIGO Connection:
The interferometer consists of two 4km long metal tubes that are 1 meter in diameter. These tubes are under vacuum and have been since the year 2000. The amount of air removed is equivalent to filling up 2.5 million footballs. The air is removed so that the Laser Light put into the beam tubes can travel at the speed of light. 186,000 m/sec or 300,000km/sec

Resources:
Scientific Explorations with Paul Doherty 2000
Physics in the Classroom.com

Safety Considerations:
None