Grades 8-11
Time: 50-70 minutes

Title: "Air Resistance and Gravity"

Synopsis: Students will experiment with objects of different size, surface area, and mass in order to better understand the concept of gravity and air resistance. This experiment will take place in groups of 3 or 4 students and is for students in grades 8 through 11. The students will have different roles in the groups such as meter stick holder, object dropper, timer and recorder.

Purpose: For students to understand the relation between air resistance, surface area, mass, gravity/acceleration, as well as force

Next Generation Science Standards:

Students who demonstrate understanding can:

HS-PS2-1.	Analyze data to support the claim that Newton's second law of motion describes the mathematical relationship among the net force on a macroscopic object, its mass, and its acceleration. [Clarification Statement: Examples of data could include tables or graphs of position or velocity as a function of time for objects subject to a net unbalanced force, such as a falling object, an object rolling down a ramp, or a moving object being pulled by a constant force.] [*Assessment Boundary: Assessment is limited to one-dimensional motion and to macroscopic objects moving at non-relativistic speeds.*]
HS-PS2-2.	Use mathematical representations to support the claim that the total momentum of a system of objects is conserved when there is no net force on the system. [Clarification Statement: Emphasis is on the quantitative conservation of momentum in interactions and the qualitative meaning of this principle.] [*Assessment Boundary: Assessment is limited to systems of two macroscopic bodies moving in one dimension.*]
HS-PS2-3.	Apply scientific and engineering ideas to design, evaluate, and refine a device that minimizes the force on a macroscopic object during a collision.* [Clarification Statement: Examples of evaluation and refinement could include determining the success of the device at protecting an object from damage and modifying the design to improve it. Examples of a device could include a football helmet or a parachute.] [*Assessment Boundary: Assessment is limited to qualitative evaluations and/or algebraic manipulations.*]
HS-PS2-4.	Use mathematical representations of Newton's Law of Gravitation and Coulomb's Law to describe and predict the gravitational and electrostatic forces between objects. [Clarification Statement: Emphasis is on both quantitative and conceptual descriptions of gravitational and electric fields.] [*Assessment Boundary: Assessment is limited to systems with two objects.*]

Objectives:

- Visually observe the relationship between surface area and gravity/acceleration.
- Think about the path of travel for the different materials
- To calculate the force that each object hits the ground with

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Introduction/Near-Peer/ Teacher Information (estimated time, 15-20 minutes)
All things fall at the same rate, even if they take longer to actually hit the ground, for example like a feather. This lab will help demonstrate how things all fall at the same rate, no matter what their weight or surface area is. For example, a feather will take a longer path back and forth while a textbook will fall straight down. Newton's Second Law, F=m *a will be used in order to calculate the force of each object on the ground. The acceleration of the feather can be found using kinematic equations for objects that fall in a straight line or gravity (9.8 m/s^2) can be used instead. If kinematics are used, it should be discovered that the acceleration is approximately gravity, although air resistance does take away a little bit of the value.

Materials:

- meter stick
- stopwatch
- objects to drop (can be varied)
    - hot wheels car
    - feather
    - textbook
    - penny
    - piece of paper
- calculator
- scale

Career Connection:

Engineers- Use Newton's Second Law as well as kinematic problems to solve problems; engineers who design cars need to study air resistance in order to design the most aerodynamic car (would have the best gas mileage). Engineers also need to understand kinematic equations. Also for designing cars, the engineers need to know how much force your car tires need to exert to accelerate your car at certain accelerations, or they need to know what size of brakes to decelerate your car at a certain rate.

Astronauts- Need to understand aerodynamics in order to get their rocket into space; they need to understand kinematics and Newton's Second Law in order to figure out how much thrust to give the rocket to take off.

Pilots- Different planes will slow down to land at different rates. Pilots need to know and understand that to make sure your plane is going to land properly. They need to know how fast to decelerate the plane in order to make sure that you don't hit the ground with too much force.

Setting Up the Lab (5 minutes)
- Have a meter stick, stop watch and a set of objects to be dropped for each group
- Have a calculator for each student
- Have a student sheet with a pre-made table for each student
- Be sure that the student sheet includes a list of equations
- Have a weighing station for the class, or a scale for each group
    -once all of their objects have been dropped, all groups will need to send one person to weigh the objects

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Procedure (10 minutes for experiment; 20-30 minutes for calculations)

1. Have students collect materials.
2. Designate one student to hold the meter stick, one student to drop the object and one person to time the fall. If there is a group of four, the fourth person can record all the data.
3. Drop the first object from a height of 1m, from rest. Make sure the timer records the time from when it is dropped until it hits the ground. Have the students fill out table accordingly.
4. Repeat step 3 until all objects have been dropped.
5. Once all of the objects have been dropped, have the timer weigh all of the objects and record their weight, while the other group members copy down the data. Have the recorder next to the stop watch student in order to record the falling times.
6. Discuss kinematic equations, do an example of how to find acceleration, and then calculate the force.
7. Have the students calculate the acceleration and force for all of their objects.

Questions to Engage the Students/Analysis:

-Does the path of the object falling affect its acceleration?
-Does air resistance play a role in an objects path?
-What objects did you expect to fall the fastest and why?
-What do you think would happen if the feather was to be placed on top of the textbook? And below?
-Which object do you think hits the ground with the most force, and why?

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Name: _____ Date: _____

In your group of three or four, you are going to discover how air resistance, mass, and gravity play a role in a how an object falls to earth.

Directions:

Step 1: Collect all items needed for the experiment (meter stick, timer, objects, calculators)

Step 2: Designate one person to hold the meter stick, one person to drop the items, one person to time the length of the fall and observe, and the fourth person can record all the data. If there are only three people, have the timer also record.

Step 3: Drop the first object, from rest, at 1m high. Make sure the timer records the time from when it is dropped, until it hits the ground. Fill out the table below accordingly.

Step 4: Repeat Step 3 with all of the objects.

Step 5: Have the person who was the recorder (if group of 3, the timer) weigh all the objects in kilograms at the designated weigh station and record their weights.

Step 6: Go through kinematic equations as a class, and then use them appropriately to calculate the force that the object hit the ground with.

Object	**Time**	**Mass**	**Path of Travel**	**Acceleration Found**	**Force w/ Acceleration Calculated**	**Force**
Lacrosse Ball						

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Kinematic Equations:

Equation	Missing Quantity
$v = v_0 + at$	$x - x_0$
$x - x_0 = v_0 t + \frac{1}{2}at^2$	v
$v^2 = v_0^2 + 2a(x - x_0)$	t
$x - x_0 = \frac{1}{2}(v_0 + v)t$	a
$x - x_0 = vt - \frac{1}{2}at^2$	v_0

x_0= initial position

x= final position

v_0= initial velocity

v= final velocity

a= acceleration

t= time

Force Equation:

F = m* a

Questions:

1.) Does the path of the object falling affect its acceleration?

2.) Does air resistance play a role in an objects path?

3.) What objects did you expect to fall the fastest and why?

4.) What do you think would happen if the feather was to be placed on top of the textbook? And below?

5.) Which object do you think hits the ground with the most force, and why?