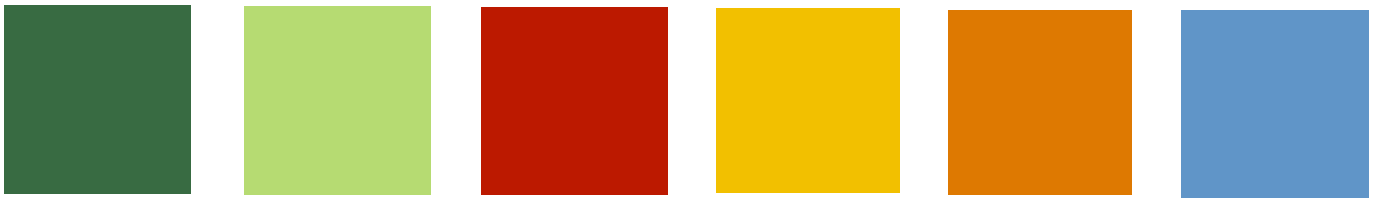


Air Resistance

Time of Lesson: 50- 60 minutes

Content Standards Addressed in Lesson:

TEKS8.6A demonstrate and calculate how unbalanced forces change the speed or direction of an object's motion (Reporting Category 2 – Readiness Standard)

TEKS8.6C investigate and describe applications of Newton's law of inertia, law of force and acceleration, and law of action-reaction such as in vehicle restrains, sports activities, amusement park rides, Earth's tectonic activities and rocket launches (Reporting Category 2 – Readiness Standard)

NSES (1996) **Grades 5-8 – Content Standard B**

- The motion of an object can be described by its position, direction of motion, and speed.
- An object that is not being subjected to a force will continue to move at a constant speed and in a straight line.
- If more than one force acts on an object along a straight line, then the forces will reinforce or cancel one another, depending on their direction and magnitude. Unbalanced forces will cause changes in the speed or direction of an object's motion.

Scientific Investigation and Reasoning Skills Addressed in Lesson:

TEKS8.2E analyze data to formulate reasonable explanations, communicate valid conclusions supported by data and predict trends

TEKS8.3A in all fields of science, analyze, evaluate, and critique scientific explanations by using empirical evidence, logical reasoning, and experimental and observational testing

TEKS8.3B use models to represent aspects of the natural world such as an atom, a molecule, space, or a geologic feature

TEKS8.3C identify advantages and limitations of models such as size, scale, properties, and materials

TEKS8.4A use appropriate tools to collect, record and analyze information, including computers

NSES (1996) **Grades 5-8 – Content Standard A**

- Use appropriate tools and techniques to gather, analyze, and interpret data.
- Develop descriptions, explanations, predictions, and models using evidence.

I. Student Prerequisite Skills/Understandings

1. A basic understanding of Newton's three laws of motion
2. Gravity is a force that pulls on objects.

II. Objectives: Students will be able to

1. Describe projectile motion without air resistance.
2. Explain the effect of air resistance on a projectile.
3. Explain the relationship between shape and air resistance.
4. Contrast the motion of a projectile without air resistance to motion with air resistance.
5. Predict the amount of air resistance an object would have relative to other objects.

III. Supplies Needed

Per pair:

- 1 computer capable of running the PhET simulation
- 5 sheets of printer paper

5E Organization

Engage (5 minutes)

Content Focus: How does an object move through the air when thrown?

Each student is given one sheet of paper. Teacher explains to students that their goal is to throw their sheet of paper as far as possible.

Questions to guide students' learning and thinking	Questions to gather information about students' understanding and learning
• What patterns or strategies did you notice about how you and your neighbors threw the paper? • Why do you think most students crumpled their paper into a ball before they threw it?	• How do you think the differences in shape contribute to the paper's motion through the air?

✓ **Checkpoint:** Students can describe what they just observed. All paper is collected.

✓

Explore – Introduction to Force Diagrams (5 minutes)

Content Focus: Gravity is a force that pulls objects towards the center of the Earth.

Teacher leads a discussion about gravity. Teacher draws a diagram of the forces acting on a woman standing outside.

Questions to guide students' learning and thinking	Questions to gather information about students' understanding and learning

• What forces are acting on you right now? • What is stopping you from moving to the center of the earth? • [reference diagram of woman] What force do we draw going downward? • [reference diagram of woman] What force do we draw going upward?	• Which direction does gravity act? How do you know? • Which force is bigger (the normal force or the force of gravity)? • Are the forces balanced or unbalanced? What evidence do you have?

✓ **Checkpoint:** Students can explain that gravity is a force that pulls on objects and that the forces are in balance on the woman standing outside.

Explore – *Projectile Motion* PhET Simulation (20 minutes)

Content Focus: demonstrate and calculate how unbalanced forces change the speed or direction of an object's motion, investigate and describe applications of Newton's law of inertia, law of force and acceleration, and law of action-reaction
Investigation Skills: analyze data to formulate reasonable explanations, use models to represent aspects of the natural world, use appropriate tools to collect, record and analyze information, including computers, identify limitations of models

Teacher defines a projectile as, "an object in the air acted on by the force of gravity" and projectile motion as, "how a projectile moves." Students begin computer simulation (see: http://phet.colorado.edu/en/simulation/projectile-motion) in pairs and are given 5 minutes for open play. After five minutes, students share what they have discovered. Teacher projects simulation in front of class and selects students to come up and point out their discoveries.

Questions to guide students' learning and thinking	Questions to gather information about students' understanding and learning
• What do you think projectile motion is? • How does a cannon ball travel when launched?	• Why are the objects moving in a curved path? • What forces are acting on the objects as they move?

✓ **Checkpoint:** Students have shared what they have discovered.

Teacher passes out PhET Simulation Sheet and gives students 20 minutes to complete activity. If needed, demonstrate the first angle together.

Questions to guide students' learning and thinking	Questions to gather information about students' understanding and learning
• How does your data compare with your neighbors' data? • What effect does mass have on your projectile's motion? Flight time? • What does the path look like? (think of terms you've used in math class) • Why should we use the same object to collect all of our data?	• What conclusions can we form about how the mass of an object affects the object's flight time? • The moon does not have air resistance. If two objects were dropped on the moon, would they land at the same time? Why?

✓ **Checkpoint:** Students have launched their object at all angles without air resistance activated.

If students have not done so, teacher instructs students to explore how air resistance affects the flight time of their object. After students explore, teacher explains that the drag coefficient is a measurement of the effect air resistance on the projectile.

Questions to guide students' learning and thinking	Questions to gather information about students' understanding and learning
• Are the flight times the same or different when air resistance is activated? • Are the times longer or shorter than before when air resistance was deactivated (not on)? • The tank shell has a drag coefficient of 0.05, what effect did air resistance have on its flight time? Try it out! • Would the blue line (no air resistance) exist in real life? Why?	• When air resistance is activated, are the forces on a projectile balanced or unbalanced? What evidence do you have? • Based on your experience, how would you define air resistance? drag coefficient? • If the flight times were the same with the tank shell, what can we conclude about the limitations of our model (the PhET simulation)? • Why do you think it is important for a tank shell to have a low drag coefficient?

Teacher holds one piece of paper flat and another perpendicular to the ground and asks which piece of paper would hit the ground first. Teacher explains that the PhET simulation approximates the shape of all the objects as spheres. Students turn to neighbors and discuss which projectiles on the simulation would be most affected by this limtation.

✓ **Checkpoint:** Students have launched their object at all angles with air resistance activated. Students can explain how the drag coefficient relates to an object's motion.

Explain with Paper Wads Activity (20 minutes)

Content Focus: investigate and describe applications of Newton's law of inertia, law of force and acceleration, and law of action-reaction, objects experience air resistance differently based on their shape and orientation
Investigation and Reasoning Skills: analyze data to formulate reasonable explanations, communicate valid conclusions supported by data and predict trends, analyze, evaluate, and critique scientific explanations by using empirical evidence, logical reasoning, and experimental and observational testing

Teacher gives each pair of students four sheets of paper and passes out Race to the Bottom Worksheet. Teacher explains that the students will drop different shapers of paper and compare how they fall. If needed, teacher shows pieces of paper crumpled in different ways (lightly crumpled, crumpled into a sphere, wadded into a ball, etc.). Students are given ten minutes to complete their activity. Teacher then discusses student observations.

Questions to guide students' learning and thinking	Questions to gather information about students' understanding and learning
• In your simulation, did mass have an effect on time in the air? Which object hit the ground first: the golf ball or the cannon ball? • What are some different things we could do to a piece of paper to change the way it's shaped? • If we don't tear the paper, but only change the paper's shape, what happens to the mass of the paper? • In Race to the Bottom, which piece of paper hit the ground the fastest? Slowest?	• How should we drop the paper for each test if we want to compare our results? Why? • What do you think contributed to the paper's flight time? • What effect does air resistance have on falling objects? • What effect does shape have on air resistance? • What effect does orientation have on air resistance? • Which piece of paper (flat, spherical, crumpled) would have the highest drag coefficient? Why?

✓ **Checkpoint:** Students are able to complete the Race to the Bottom activity, communicate their results to the class and engage in a group discussion.

Elaborate (5-10 minutes)

Content Focus: relate a real world example to laboratory experiences

Teacher leads a group discussion of the differences between cars and semi-trucks. Teacher defines aerodynamic as having a shape that reduces the drag from air moving past an object.

Questions to guide students' learning and thinking	Questions to gather information about students' understanding and learning
• What qualities make a car aerodynamic? • Why do cars need to be aerodynamic? • How aerodynamic are semi-trucks?	• If you wanted to make a semi-truck more aerodynamic, what would you do? Why?

✓ **Checkpoint**: Students can describe how the shape of a car contributes to its ability to overcome air resistance.

Evaluate

Use evaluations in attached documents.

Name: _____

PhET Simulation Sheet

What object are you going to study? _____
What is the mass of the object you are studying? _____

Angle (degrees)	Flight Time (seconds) without air resistance	Flight Time (seconds) with air resistance
30		
45		
60		
70		

1. Draw the shape of your object's path. What type of graph does this remind you of?

2. What can you conclude about the relationship between the angle and the flight time of your object?

3. Turn to your neighbors!

What object did they have? _____

Did they have the same flight time as your group? _____

4. Look back at Part #1. Are the flight times the same when air resistance activated? If not, how different are the flight times?

5. What do you think is responsible for the difference in flight times? Explain.

6. After talking about your results with the class, what effect does mass have on the flight time of your projectile **before air resistance is activated**?

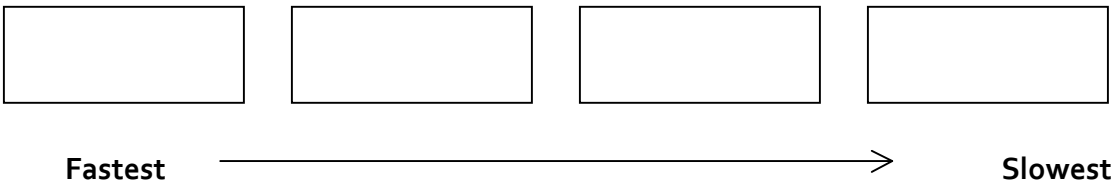
Name: _____

Race to the Bottom

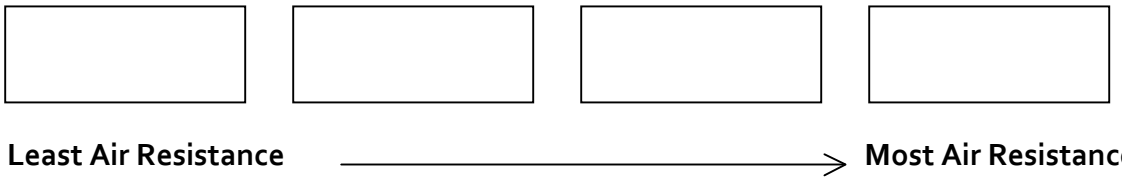
Drop the pieces of paper together so that you can compare them to each other Use words to describe how it falls. Consider: Does it fall straight down? Does it drift from side to side?

Shape	How did it fall?
Flat	
Lightly Crumpled	
Crumpled sphere	
Waded Ball	

Rate the following in the boxes below: flat, lightly crumpled, crumpled sphere, waded ball.



Rate the following in the boxes below: flat, lightly crumpled, crumpled sphere, waded ball.



1. Which shape experienced the most air resistance? What makes it different from the other shapes?

2. Which shape experienced the least amount of air resistance? What makes it difference from the other shapes?

Evaluation Questions

1. What affect does mass have on flight time with air resistance? Explain.

2. What affect does mass have on flight time without air resistance? Explain.

3. Why does a flat piece of paper experience more air resistance than a paper ball? Think about the differences between the two.

4. If you were skydiving would you want a 10 ft^2 parachute or a 100 ft^2 parachute? Use your observations made in your experiment to justify your decision. Why?

5. Suppose that air resistance did not exist. Would it matter which parachute you used? Justify your answer based on the results from your PhET simulation sheets.

6. How does an object's drag coefficient affect its flight? Use an example.