Lesson Title	Acme helicopter lab
Length of Lesson	1 week
Created By	Henry Stauffenberg IV, Matthew Lee
Subject	Physics
Grade Level	9-12 (Physics)
State Standards	Physics: 1 a, b, c, d, e, f; 2 a, b, c
DOK Level	Physics: 3
DOK Application	Validate, inquire, organize, collect, interpret, investigate, connect, explain, prove, draw conclusions, graph, predict, contrast, compare
National Standards	9 – 12 A: Inquiry; B: Physical Science; E: Science and Technology
Graduate Research Element	Working with excel for statistical analysis and presentation of collected data drawn from experimentation

Student Learning Goal:

The purpose of this lesson is to validate or invalidate $F_L = 1/2\rho v^2 C_L A$ (force of lift) and $F_D = 1/2\rho v^2 C_D A$ (force of drag) through testing and design of paper helicopters. To practice scientific process (**observe, describe, process, and interpret**). To have the students inquire and ask and or answer questions such as; how are these two equations effective at examining drag force and lift force? What is the relationship between lift and drag forces? By using (total force = gravity + lift + drag) the lift equation will calculate the drag force; however, depending of the value of C_L (coefficient of lift) the calculated drag force is sometimes different from the actual drag force equation ($F_D = 1/2\rho v^2 C_D A$) why? The two formulas, given the same set of data, should yield the same drag force right? Ultimately to compare/contrast and investigate, interpret, and explain the two formulas with respect to each other and vector forces. Also to investigate the effects of rotation on lift and drag forces.

The students will understand that both formulas will and wont make sense when it comes to comparing, contrasting, and validation. There are no clear answers and each formula will be valid/invalid depending on the circumstances/parameters of the research. **They will learn to continually ask themselves does this make sense?** and through this process will drive themselves forward into deeper investigation/understanding of what is going on between lift and drag forces and what is known, known, or unclear.

Mississippi State Standards

Physics: 1: (a) Use current technologies such as CD-ROM, DVD, Internet, and on-line data search to explore current research related to a specific topic; (b) Clarify research questions and design laboratory investigations; (c) Demonstrate the use of scientific inquiry and methods to formulate, conduct, and evaluate laboratory investigations; (d) Organize data to construct graphs to draw conclusions and make inferences; (e) Evaluate procedures, data, and conclusions to critique the scientific validity of research; (f)

Formulate and revise scientific explanations and models using logic and evidence; 2: (a) Use inquiry to investigate and develop an understanding of the kinematics and dynamics of physical bodies; (b) Analyze, describe, and solve problems by creating and utilizing graphs of one-dimensional motion; (c) Analyze real-world applications to draw conclusions about Newton's three laws of motion.

National Science Education Standards of Content 9 – 12

A: Inquiry: identify questions and concepts that guide scientific investigations

- Students should formulate a testable hypothesis and demonstrate the logical connections between the scientific concepts guiding the hypothesis and the design of an experiment. They should demonstrate appropriate procedures, a knowledge base, and a conceptual understanding of scientific investigations.

B: Physical Science: motion and forces

- Objects change their motion only when net force is applied. Laws of motion are used to calculate precisely the effects of forces on the motion of objects. The magnitude of the change in motion can calculated using the relationship F=ma, which is independent of the nature of the force. Whenever one object exerts force on another, a force equal in magnitude and opposite in direction is exerted on the first object.
- Gravitation is a universal force that each mass exerts on any other mass. The strength of the gravitational attractive force between two masses is proportional to the square of the distance between them.

E: Science and Technology: understanding about science and technology

- Scientists in different disciplines ask different questions, use different methods of investigation, and accept different types of evidence to support their explanations. Many scientific investigations require the contributions of individuals from different disciplines, including engineering. New disciplines of science, such as geophysics and biochemistry often emerge at the interface of two older disciplines.

Materials Needed (supplies, hand-outs, resources):

Computer, excel, logger pro program, meter stick, motion camera, paper, tape and or paperclips, instructions for a basic helicopter design, and handout of sources useful for inquiry and investigation of lift and drag forces with respect to auto rotation. See handouts attached (or in zip folder) for: helicopter design instructions and 3 supportive documents (all in one word file) needed for research and descriptions. A picture of board notes is also included for angle of attack measurements.

Lesson Performance Task/Assessment:

- Ability to use excel and logger pro to collect free fall helicopter data
- Ability to graph and interpret data and utilize supportive handouts
- Student's being able to validate/invalidate given formulas

- Ability to create a report explaining their conclusion and prove their validation/invalidation of given formulas
- Having many more questions based from their inquiry and independent research
- Ability to define, compare, contrast, and connect lift and drag forces to total net force, force of gravity, acceleration, terminal velocity, and other concepts based on Newton's three laws of motion
- Successfully complete independent research and lab report

Lesson Relevance to Performance Task and Students:

- To practice real world graduate research element by validation/invalidation of formulas through independent research, inquiry based investigation/experimental design, manipulation and regression fit of data, and utilization of resources
- To develop student skills with new and useful technology, especially when it comes to data manipulation using excel
- To introduce experimentation design and data analysis that graduate research utilizes
- To understand by doing and following scientific design; observe, describe, process, and interpret
- To promote inquiry about auto rotation, vector forces, acceleration, velocity, and lift/drag force by having students do independent research and applying what they have learned
- To use graphical and statistical results to prove, explain, and answer concepts or questions and validate/invalidate formulas

Anticipatory Set/Capture Interest:

You are aerospace engineers employed by an American company called Acme inc. Acme wants you to design and build helicopters to validate or invalidate the force of lift and force of drag formulas, $F_L = 1/2\rho v^2 C_L A$ (force of lift) and $F_D = 1/2\rho v^2 C_D A$ (force of drag). Unfortunately you are on a cheap budget and on short notice. The Germans (Stuaffenberg aerodesign inc.) lead in the race to unlock the secrets of the lift and drag formulas. A successful Funderburk class01 helicopter was already tested with very promising results; Acme spies have obtained this data and placed it in the Global folder/Funderburk/AP Physics. You have until next week to beat the Stauffenberg company from validating or invalidating the two formulas. Unfortunately you are on a cheap budget and on short notice. As you look around all you can find is a piece of paper, tape, meter stick, and a phone useful for taking motion pictures. With these items at your disposal you will have to design and test your own American made paper helicopters. Acme will provide you with logger pro and excel to collect and process your data. Good luck and may the best helicopter win!

Guided Practice:

Briefly show how to build a simple helicopter out of one strip of paper (instruction handout). Using the camera, and meter stick for reference, record a single flight free fall

drop and show how to use logger pro to record and process data into excel. Make note that the resultant graph (plotted with respect to velocity and time) should have two noticeable parts. The first part is a curved string of data for fall of object before auto rotation and the second part being a linear string of data for object with auto rotation. Each part will need its own best fit and regression that the students will have to choose based from previous calculus experience. Hand out the supportive sources (mentioned in materials) and explain to the students that they will be using these sources in conjunction of what they can independently research to validate/invalidate these two formulas; $F_L = 1/2\rho v^2 C_L A$ (force of lift) and $F_D = 1/2\rho v^2 C_D A$ (force of drag). Explain that they are doing graduate work by inquiring, investigating, and explaining the results of their research. Ask a few questions (stated in learning goal) to stimulate and guide student inquiry. What they find will be both in a group and independent practice. What ever connections, questions, conclusions, thoughts, or any other scientific inquiry will be written down in a report to be later discussed in class. Explain that they will be doing the whole scientific process (observe, describe, process, and interpret). Then let the students go to explore their creativity with helicopter design and data analysis. Be sure to explain the angle of attack principal described in the handouts if the students show signs of significant struggle. Half way through the week guide the students through working with the formulas to calculate coefficient of lift and plug in their data into each equation. Essentially walk through part of the inquiry by taking two velocity numbers, plug into both equations, use the handouts and walk through finding of useful info, and then organizing results from both equations and asking how the answers compare and or what does this mean? what are the patterns? Does this make sense?

Independent Practice:

Analysis of graphical data, utilization of resources such as the handouts, and writing of a report. The whole activity is independent research when group work is not available.

Remediation and/or Enrichment:

Remediation: individual IEP, partner with helpful student, make lesson more walk through intensive.

Enrichment: Ask for a regression (create an equation to fit data) and have them answer greater questions of intrigue generated by the professor such as; what is the orientation of the vector forces? draw them out, Why wont the coefficient of lift formula work for greater angles? Prove to me that this formula is better than this one in this situation.

Check(s) for Understanding:

- Ability to use excel/logger pro equipment and gather complete data
- Ability to explain/prove their validation conclusion in their report
- Ability to answer questions asked (or seeded) by the instructor
- Acknowledgment that there are no clear answers and each formula will be valid/invalid depending on the circumstances/parameters of the research

- Ability to express/present their findings, in their own words, to tie in what they have learned in class with what they have researched on their own
- Ability to define and explain the relationship between lift and drag forces, especially with respect to terminal velocity, acceleration, and vector forces.

Closure:
Optional: have a contest for the helicopter that generates most lift force. Have a class discussion on what the students presented and answer any questions that remain from the lab activity overall. Let the students know that what they just did in one week is essentially part of what a grad student does on a regular basis. Also, that the skills they developed today will be important and valued in graduate study.

Possible Alternate Subject Integrations:

Calculus: Regression models, line equations, vector math, and formula/algebraic calculations

Teacher notes:
none