2 Aerodynamics

Content Area: **Science**
Course(s): **Aerospace Engineering**
Time Period: **Semester 1**
Length: **4 Weeks**
Status: **Published**

Standards

SCI.9-12.HS-PS1-2.1.1	students observe patterns in systems at different scales and cite patterns as empirical evidence for causality in supporting their explanations of phenomena. They recognize classifications or explanations used at one scale may not be useful or need revision using a different scale; thus requiring improved investigations and experiments. They use mathematical representations to identify certain patterns and analyze patterns of performance in order to reengineer and improve a designed system.
SCI.9-12.HS-PS3-5.2.1	Develop and use a model based on evidence to illustrate the relationships between systems or between components of a system.
SCI.9-12.HS-PS2-3.6.1	Apply scientific ideas to solve a design problem, taking into account possible unanticipated effects.
SCI.9-12.HS-PS3-3.6.1	Design, evaluate, and/or refine a solution to a complex real-world problem, based on scientific knowledge, student-generated sources of evidence, prioritized criteria, and tradeoff considerations.
SCI.9-12.HS-PS2-6.8	Obtaining, evaluating, and communicating information in 9–12 builds on K–8 and progresses to evaluating the validity and reliability of the claims, methods, and designs.
SCI.9-12.HS-PS2-6.8.1	Communicate scientific and technical information (e.g. about the process of development and the design and performance of a proposed process or system) in multiple formats (including orally, graphically, textually, and mathematically).
SCI.9-12.HS-PS3-3.ETS1.A	Defining and Delimiting Engineering Problems
SCI.9-12.HS-PS3-3.ETS1.A.1	Criteria and constraints also include satisfying any requirements set by society, such as taking issues of risk mitigation into account, and they should be quantified to the extent possible and stated in such a way that one can tell if a given design meets them.
SCI.9-12.HS-PS2-3.ETS1.C	Optimizing the Design Solution
SCI.9-12.HS-PS2-3.ETS1.C.1	Criteria may need to be broken down into simpler ones that can be approached systematically, and decisions about the priority of certain criteria over others (trade-offs) may be needed.
CCSS.Math.Content.HSA-CED	Creating Equations
CCSS.Math.Content.HSA-CED.A	Create equations that describe numbers or relationships
CCSS.Math.Content.HSA-CED.A.1	Create equations and inequalities in one variable and use them to solve problems.
CCSS.Math.Content.HSA-CED.A.2	Create equations in two or more variables to represent relationships between quantities; graph equations on coordinate axes with labels and scales.
CCSS.Math.Content.HSA-CED.A.3	Represent constraints by equations or inequalities, and by systems of equations and/or inequalities, and interpret solutions as viable or non-viable options in a modeling context.
CCSS.Math.Content.HSA-CED.A.4	Rearrange formulas to highlight a quantity of interest, using the same reasoning as in solving equations.
CCSS.Math.Content.HSA-REI	Reasoning with Equations and Inequalities
CCSS.Math.Content.HSA-REI.A	Understand solving equations as a process of reasoning and explain the reasoning
CCSS.Math.Content.HSA-REI.B	Solve equations and inequalities in one variable

CCSS.Math.Content.HSA-REI.B.3	Solve linear equations and inequalities in one variable, including equations with coefficients represented by letters.
CCSS.Math.Content.HSA-REI.B.4	Solve quadratic equations in one variable.
STEM.9-12.1	Engineering & Technology
STEM.9-12.9.4.12.O.(1).3	Demonstrate the ability to select, apply, and convert systems of measurement to solve problems.
STEM.9-12.9.4.12.O.(1).4	Demonstrate the ability to use Newton's laws of motion to analyze static and dynamic systems with and without the presence of external forces.
STEM.9-12.9.4.12.O.(1).6	Explain relationships among specific scientific theories, principles, and laws that apply to technology and engineering.
STEM.9-12.9.4.12.O.(1).7	Use mathematics, science, and technology concepts and processes to solve problems in projects involving design and/or production (e.g., medical, agricultural, biotechnological, energy and power, information and communication, transportation, manufacturing, and construction).
STEM.9-12.9.4.12.O.(2).1	Develop an understanding of how science and mathematics function to provide results, answers, and algorithms for engineering activities to solve problems and issues in the real world.
STEM.9-12.9.4.12.O.(2).2	Apply science and mathematics when developing plans, processes, and projects to find solutions to real world problems.
STEM.9-12.9.4.12.O.4	Select and employ appropriate reading and communication strategies to learn and use technical concepts and vocabulary in practice.
STEM.9-12.9.4.12.O.12	Develop and interpret tables, charts, and figures to support written and oral communications.
	Emphasis is on both qualitative and quantitative evaluations of devices. Examples of devices could include Rube Goldberg devices, wind turbines, solar cells, solar ovens, and generators. Examples of constraints could include use of renewable energy forms and efficiency.
	All clusters rely on effective oral and written communication strategies for creating, expressing, and interpreting information and ideas that incorporate technical terminology and information.
	Include equations arising from linear and quadratic functions, and simple rational and exponential functions.

Enduring Understandings

1. Scientists and engineers can develop mathematical models that relate the variables that quantify a phenomena, such as the development of aerodynamic lift, even though these models do not explain why the phenomena occur.
2. Forces can act over an area, rather than at a single discrete location, and this distribution of force over an area can best be quantified as pressure.
3. Non-dimensional coefficients; such as friction, lift, and drag coefficients; are a common way of empirically expressing the relationship between variables when the underlying theory is too complex, chaotic, misunderstood to be modeled from first principles.
4. Small changes to the nature of fluid flow (such as air) near the surface of an object (such as a wing) within the boundary layer can have large consequences on the overall macroscopic flow around an object.
5. The act of producing aerodynamic lift also develops aerodynamic drag due to the unavoidable creation of wingtip vortices.

Essential Questions

1. What factors contribute to the generation of the aerodynamic forces of lift and drag?
2. How can a complex phenomena, such as the generation of lift or drag, be quantified with a unitless coefficient?
3. What different mechanisms contribute to the aerodynamic drag acting on an object and how can the overall drag on an object be reduced?

Knowledge and Skills

Knowledge:

- An airfoil is a geometric shape designed to maximize the production of lift while minimizing the production of drag.
- Since they are both aerodynamic forces, lift and drag are affected by the same basic factors, namely: (1) the density of the air passing over the object, (2) the shape of the object, (3) the angle at which the flow passes over the object, (4) the cross sectional geometry of the object, and (5) some characteristic area that defines the size of the object.
- The lift coefficient is a non-dimensional coefficient that defines how effective an airfoil is at generating lift based on its geometry and the angle of attack of the oncoming air.
- The drag coefficient is a non-dimensional coefficient that defines how much drag an object creates, based on its geometry and the angle of attack of the oncoming air.
- All aerodynamic coefficients are a ratio of the aerodynamic pressure generated by the object in the flow and the dynamic pressure of the flow.
- Lift increases linearly with increasing angle of attack until the flow detaches from the wing at the critical angle of attack. At this point, the wing is said to be “stalled”.
- Drag can be categorized as parasite drag, or drag due to the air passing over and around an object; and induced drag, the drag created as a by-product of the production of lift.
- Parasite drag can further be broken into two categories: (1) skin friction drag associated with the viscosity of the air sliding over a surface, and (2) pressure drag due to the low pressure wake generated behind any “buff” body
- The nature of parasite drag is largely a function of the boundary layer, the region of the flow near the surface of the object, and whether it is laminar or turbulent.
- Induced drag is a by-product of lift due to the production of wingtip vortices, which induce a downwash to the flow and generate a component of lift parallel to the motion of the object, which is essentially a form of drag.
- The planform, or shape of a wing when viewed from above, affects the production of wingtip vortices and downwash, and thus affects the induced drag created by an airplane.
- As airspeed increases, parasite drag increases while induced drag decreases, and visa versa. Thus, there is a velocity of minimum total drag.

Skills:

- Students will be able to quantify aerodynamic force coefficients based on measurements of flow and force.

- Students will be able to evaluate an aircraft and predict its behavior/capabilities based on its aerodynamic characteristics.
- Students will be able to define basic ratios that predict the performance of an airplane design, such as wing loading, power loading, tail volume, etc.
- Students will be able to view the slope of a function as the rate of change between two variables, such as the slope of the lift curve as the rate at which lift changes with changing angle of attack.
- Students will be able to define the max or minimum of a function as the point where the tangent line to the function is horizontal, such as the velocity of minimum drag as occurring where the slope of the drag vs. velocity graph equals zero.

Transfer Goals

- Ability to infer physical meaning from the mathematical trends on a line graph that indicate linearity, proportionality, max/min, slope, and y-intercept.
- Ability to work with non-dimensional coefficients to empirically quantify complex phenomena, such as friction.
- Ability to identify the maximum and minimum range values of a function by identifying locations where the tangent line is horizontal.

Assessments

https://docs.google.com/document/d/1wR7bQF-8AQoRrt0g4C3hKja0yjwDjC9_BiAmONWbTcI/edit?usp=sharing

Modifications

https://docs.google.com/document/d/1ODqaPP69YkcFiyG72fIT8XsUIe3K1VSG7nxuc4CpCec/edit?usp=sharing