

I. Real Wings: Induced Drag & Planform

Content Area: **Science**
Course(s): **CAD Architect**
Time Period: **Marking Period 1**
Length: **1**
Status: **Published**

Assessment

"Do Now" Activities

"Exit Ticket" Activities

Practice Problem Worksheets

Quizzes

Standards

SCI.9-12.HS-ETS1-2	Design a solution to a complex real-world problem by breaking it down into smaller, more manageable problems that can be solved through engineering.
SCI.9-12.HS-ETS1-3	Evaluate a solution to a complex real-world problem based on prioritized criteria and trade-offs that account for a range of constraints, including cost, safety, reliability, and aesthetics, as well as possible social, cultural, and environmental impacts.
SCI.9-12.HS-ETS1-4	Use a computer simulation to model the impact of proposed solutions to a complex real-world problem with numerous criteria and constraints on interactions within and between systems relevant to the problem.
SCI.9-12.HS-PS3-1	Create a computational model to calculate the change in the energy of one component in a system when the change in energy of the other component(s) and energy flows in and out of the system are known.
SCI.9-12.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.

Enduring Understandings

Students will come to understand:

1. The three-dimensional affect of a wingtip vorticies creates an upwash ahead of a wing an a downwash behind a wing, which create an induced angle of attack and induced drag.
2. While induced drag is an unavoidable consequence of a real, finite-span wing, the magnitude of this induced drag force is a function of the wing's aspect ratio: increasing aspect ratio decreases induced drag.
3. Induced drag increases with: decreasing airspeed, increasing lift, and increasing altitude.
4. The aspect ratio of a wing changes the slope of the lift curve; decreasing aspect ratio decreases the

slope of the lift curve, and thus the aircraft's sensitivity to changes in angle of attack.

Essential Questions

The following questions will guide student inquiry:

- How does induced drag differ from profile drag?
- What are the practical aerodynamic consequences associated with changing the aspect ratio of a wing?
- What are the practical structural design consequences associated with changing the aspect ratio of a wing?

Knowledge and Skills

Unit Content:

The spanwise flow of air over a wing and the wingtip vortices created as high pressure air from below the wing spills around the tip to the low pressure region above the wing direct the lift vector rearward. The horizontal component of this aft-pointing lift vector represents a new force of drag known as induced drag. Induced drag is an unavoidable consequence of any finite span wing and it is function of the wing's planform. This fact dictates planform of real wings. This unit will explore induced drag, the factors that affect it, and how aircraft are designed with these factors in mind. Specifically, this unit explores how induced drag varies with aspect ratio. The next unit will explore the behavior of an actual wing as functions of taper and sweepback, respectively.

- Creation and definition of induced drag
- The induced drag coefficient and equation for induced drag
- The induced drag equation & relationship to aspect ratio (3 days)
- Effect of lift on induced drag
- Effect of Altitude on Induced Drag (1 day)
- Effect of Speed on Induced Drag
- Effect of Aspect Ratio on Induced Drag (1 day)

Science, Technology, Engineering, Mathematics, and/or Aerospace Skill(s):

- Practical Consequences: Landing attitude (2 days)

Resources

Textbook(s):

Hurt, H. H. (1965). *Aerodynamics for Naval aviators*. Washington, DC: Federal Aviation Administration.

Cessna Aircraft Company. (1977). *Pilots operating handbook: Cessna 172*. Wichita, KS: Cessna Aircraft Company.

Federal Aviation Administration. (2013). *The pilots handbook of aeronautical knowledge*. Washington, DC: Author.

Lab Equipment:

Pasco Low Speed Wind Tunnel

Balsa tools to create airfoil sections

Foam cutter and foam cutting tools to create airfoil sections

Balsa gliders

Video Camera/digital camera

Computer Software:

Microsoft Excel

Foilsim

NASA Site