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| **Lesson 1.2 Physics of Flight** |

**Preface**

Flying inspires imagination in many people. In the last lesson students explored the rich history of leaving the Earth’s surface. In this lesson students will see how science, engineering and imagination come together to make flying possible. Students will apply aerodynamic equations to solve aerospace engineering problems and apply that knowledge to design, build and test gliders.

**Concepts**

1.     Aircraft have fixed and moveable surfaces to control forces and change flight direction.

2.     The center of gravity of an object is where its weight is concentrated.

3.     Four major forces act on an aircraft flying in the Earth’s atmosphere.

4.     Atmospheric conditions impact aircraft performance.

5.     Lift and drag are generated by fluid flow around an airfoil.

6.     Aircraft performance can be simulated in a safe and cost effective environment.

7.     Wind tunnels allow the performance of shapes to be tested in real fluid flow.

8.     Gliders are designed to fly long distances without a system to produce thrust.

**Standards and Benchmarks Addressed**

***Standards for Technological Literacy***

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| **Standard 1:  Students will develop an understanding of the characteristics and scope of technology.** |
| **BM J:** | The nature and development of technological knowledge and processes are functions of the setting. |
| **BM K:** | The rate of technological development and diffusion is increasing rapidly.  |
| **BM L:** | Inventions and innovations are the results of specific, goal-directed research. |
| **BM M:** | Most development of technologies these days is driven by the profit motive and the market. |
| **Standard 2:  Students will develop an understanding of the core concepts of technology.** |
| **BM W:** | Systems’ thinking applies logic and creativity with appropriate compromises in complex real-life problems.  |
| **BM X:** | Systems, which are the building blocks of technology, are embedded within larger technological, social, and environmental systems.  |
| **BM Y:** | The stability of a technological system is influenced by all of the components in the system especially those in the feedback loop.  |
| **BM Z:** | Selecting resources involves trade-offs between competing values, such as availability, cost, desirability, and waste.  |
| **BM AA:** | Requirements involve the identification of the criteria and constraints of a product or system and the determination of how they affect the final design and development.  |
| **BM BB:** | Optimization is an on going process or methodology of designing or making a product and is dependent on criteria and constraints. |
| **BM CC:** | New technologies create new processes.  |
| **BM DD:** | Quality control is a planned process to ensure that a product, service, or system meets established criteria.  |
| **BM EE:** | Management is the process of planning, organizing, and controlling work.  |
| **BM FF:** | Complex systems have many layers of controls and feedback loops to provide information. |
| **Standard 3:  Students will develop an understanding of the relationships** **among technologies and the connections between technology and other fields of study.** |
| **BM G:** | Technology transfer occurs when a new user applies an existing innovation developed for one purpose in a different function |
| **BM H:** | Technological innovation often results when ideas, knowledge, or skills are shared within a technology, among technologies, or across other fields.  |
| **BM I:** | Technological ideas are sometimes protected through the process of patenting. The protection of a creative idea is central to the sharing of technological knowledge. |
| **BM J:** | Technological progress promotes the advancement of science and mathematics. Likewise, progress in science and mathematics leads to advances in technology. |
| **Standard 4:  Students will develop an understanding of the cultural, social, economic, and political effects of technology.** |
| **BM H:** | Changes caused by the use of technology can range from gradual to rapid and from subtle to obvious.  |
| **BM I:** | Making decisions about the use of technology involves weighing the trade-offs between the positive and negative effects.  |
| **BM J:** | Ethical considerations are important in the development, selection, and use of technologies.  |
| **BM K:** | The transfer of a technology from one society to another can cause cultural, social, economic, and political changes affecting both societies to varying degrees. |
| **Standard 6:  Students will develop an understanding of the role of society in the development and use of technology.**  |
| **BM H:** | Different cultures develop their own technologies to satisfy their individual and shared needs, wants, and values.  |
| **BM I:** | The decision whether to develop a technology is influenced by societal opinions and demands, in addition to corporate cultures.   |
| **Standard 7:  Students will develop an understanding of the influence of** **technology on history.**  |
| **BM G:** | Most technological development has been evolutionary, the result of a series of refinements to a basic invention.  |
| **BM H:** | The evolution of civilization has been directly affected by, and has in turn affected, the development and use of tools and materials.  |
| **BM I:** | Throughout history, technology has been a powerful force in reshaping the social, cultural, political, and economic landscape.  |
| **BM O:** | The Information Age places emphasis on the processing and exchange of information. |
| **Standard 8:  Students will develop an understanding of the attributes of design.**  |
| **BM H:** | The design process includes defining a problem, brainstorming, researching and generating ideas, identifying criteria and specifying constraints, exploring possibilities, selecting an approach, developing a design proposal, making a model or prototype, testing and evaluating the design using specifications, refining the design, creating or making it, and communicating processes and results.   |
| **BM I:** | Design problems are seldom presented in a clearly defined form.  |
| **BM J:** | The design needs to be continually checked and critiqued, and the ideas of the design must be redefined and improved.   |
| **BM K:** | Requirements of a design, such as criteria, constraints, and efficiency, sometimes compete with each other. |
| **Standard 9:  Students will develop an understanding of engineering design.**  |
| **BM I:** | Established design principles are used to evaluate existing designs, to collect data, and to guide the design process.  |
| **BM J:** | Engineering design is influenced by personal characteristics, such as creativity, resourcefulness, and the ability to visualize and think abstractly. |
| **BM K:** | A prototype is a working model used to test a design concept by making actual observations and necessary adjustments.  |
| **BM L:** | The process of engineering design takes into account a number of factors. |
| **Standard 10:  Students will develop an understanding of the role of** **troubleshooting, research and development, invention and innovation, and experimentation in problem solving.** |
| **BM I:** | Research and development is a specific problem-solving approach that is used intensively in business and industry to prepare devices and systems for the marketplace.  |
| **BM J:** | Technological problems must be researched before they can be solved.  |
| **BM K:** | Not all problems are technological, and not every problem can be solved using technology.  |
| **BM L:** | Many technological problems require a multidisciplinary approach. |
| **Standard 11:  Students will develop abilities to apply the design process.**  |
| **BM M:** | Identify the design problem to solve and decide whether or not to address it. |
| **BM N:** | Identify criteria and constraints and determine how these will affect the design process.   |
| **BM O:** | Refine a design by using prototypes and modeling to ensure quality, efficiency, and productivity of the final product.   |
| **BM P:** | Evaluate the design solution using conceptual, physical, and mathematical models at various intervals of the design process in order to check for proper design and to note areas where improvements are needed.   |
| **BM Q:** | Develop and produce a product or system using a design process.    |
| **BM R:** | Evaluate final solutions and communicate observation, processes, and results of the entire design process, using verbal, graphic, quantitative, virtual, and written means, in addition to three-dimensional models. |
| **Standard 12:  Students will develop the abilities to use and maintain technological products and systems.**  |
| **BM L:** | Document processes and procedures and communicate them to different audiences using appropriate oral and written techniques.  |
| **BM O:** | Operate systems so that they function in the way they were designed.  |
| **BM P:** | Use computers and calculators to access, retrieve, organize and process, maintain, interpret, and evaluate data and information in order to communicate. |
| **Standard 13:  Students will develop the abilities to assess the impacts of products and systems.**  |
| **BM J:** | Collect information and evaluate its quality.  |
| **BM L:** | Use assessment techniques, such as trend analysis and experimentation to make decisions about the future development of technology.   |
| **Standard 16:  Students will develop an understanding of and be able to select and use energy and power technologies.**  |
| **BM J:** | Energy cannot be created or destroyed; however, it can be converted from one form to another. |
| **BM K:** | Energy can be grouped into major forms: thermal, radiant, electrical, mechanical, chemical, nuclear, and others.   |
| **Standard 17:  Students will develop an understanding of and be able to select and use information and communication technologies.**  |
| **BM L:** | Information and communication technologies include the inputs, processes, and outputs associated with sending and receiving information. |
| **BM M:** | Information and communication systems allow information to be transferred from human to human, human to machine, machine to human, and machine to machine.  |
| **BM N:** | Information and communication systems can be used to inform, persuade, entertain, control, manage, and educate.  |
| **BM P:** | There are many ways to communicate information, such as graphic and electronic means. |
| **BM Q:** | Technological knowledge and processes are communicated using symbols, measurement, conventions, icons, graphic images, and languages that incorporate a variety of visual, auditory, and tactile stimuli. |
| **Standard 18:  Students will develop an understanding of and be able to select and use transportation technologies.**  |
| **BM J:** | Transportation plays a vital role in the operation of other technologies, such as manufacturing, construction, communication, health and safety, and agriculture.  |
| **Standard 19:  Students will develop an understanding of and be able to select and use manufacturing technologies.**  |
| **BM L:** | Servicing keeps products in good operating condition.  |
| **BM O:** | Manufacturing systems may be classified into types, such as customized production, batch production, and continuous production.  Optimization is an on going process or methodology of designing or making a product and is dependent on criteria and constraints. |
| **BM P:** | The interchangeability of parts increases the effectiveness of manufacturing processes.   |
| **Standard 20:  Students will develop an understanding of and be able to select and use construction technologies.**  |
| **BM J:** | Infrastructure is the underlying base or basic framework of a system.   |
| **BM K:** | Structures are constructed using a variety of processes and procedures.   |
| **BM L:** | The design of structures includes a number of requirements.   |
| **BM M:** | Structures require maintenance, alteration, or renovation periodically to improve them or to alter their intended use.   |
| **BM N:** | Structures can include prefabricated materials. |

***National Science Education Standards***

**Unifying Concepts and Processes:**  As a result of activities in grades K-12, all students should develop understanding and abilities aligned with the following concepts and processes.

        **Systems, order, and organization**

        **Evidence, models, and explanation**

        **Change, constancy, and measurement**

        **Form and function**

**Science As Inquiry Standard A:** As a result of activities in grades 9-12, all students should develop

        **Understanding about scientific inquiry**

**Physical Science Standard B:** As a result of activities in grades 9-12, all students should develop an understanding of

        **Motions and forces**

        **Conservation of energy and increase in disorder**

**Earth and Space Science Standard D:** As a result of activities in grades 9-12, all students should develop an understanding of

        **Energy in the earth system**

**Science and Technology Standard E:** As a result of activities in grades 9-12, all students should develop

        **Abilities of technological design**

        **Understandings about science and technology**

**History and Nature of Science Standard G:** As a result of activities in grades 9-12, all students should develop understanding of

        **Science as a human endeavor**

***Principles and Standards for School Mathematics***

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| **Number and Operations** | Instructional programs from pre-kindergarten through grade 12 should enable all students to understand numbers, ways of representing numbers, relationships among numbers, and number systems; understand meanings of operations and how they relate to one another; compute fluently and make reasonable estimates. |
| **Algebra** | Instructional programs from pre-kindergarten through grade 12 should enable all students to understand patterns, relations, and functions; represent and analyze mathematical situations and structures using algebraic symbols; use mathematical models to represent and understand quantitative relationships; analyze change in various contexts. |
| **Geometry** | Instructional programs from pre-kindergarten through grade 12 should enable all students to analyze characteristics and properties of two- and three-dimensional geometric shapes and develop mathematical arguments about geometric relationships; specify locations and describe spatial relationships using coordinate geometry and other representational systems; apply transformations and use symmetry to analyze mathematical situations; use visualization, spatial reasoning, and geometric modeling to solve problems. |
| **Measurement** | Instructional programs from pre-kindergarten through grade 12 should enable all students to understand measurable attributes of objects and the units, systems, and processes of measurement; apply appropriate techniques, tools, and formulas to determine measurements. |
| **Problem Solving** | Instructional programs from pre-kindergarten through grade 12 should enable all students to build new mathematical knowledge through problem solving; solve problems that arise in mathematics and in other contexts; apply and adapt a variety of appropriate strategies to solve problems; monitor and reflect on the process of mathematical problem solving. |
| **Communication** | Instructional programs from pre-kindergarten through grade 12 should enable all students to organize and consolidate their mathematical thinking through communication; communicate their mathematical thinking coherently and clearly to peers, teachers, and others; analyze and evaluate the mathematical thinking and strategies of others; use the language of mathematics to express mathematical ideas precisely. |
| **Connections** | Instructional programs from pre-kindergarten through grade 12 should enable all students to recognize and use connections among mathematical ideas; understand how mathematical ideas interconnect and build on one another to produce a coherent whole; recognize and apply mathematics in contexts outside of mathematics. |
| **Representation** | Instructional programs from pre-kindergarten through grade 12 should enable all students to create and use representations to organize, record, and communicate mathematical ideas; select, apply, and translate among mathematical representations to solve problems; use representations to model and interpret physical, social, and mathematical phenomena. |

***Standards for English Language Arts***

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| **Standard 4** | Students adjust their use of spoken, written, and visual language (e.g. conventions, style, vocabulary) to communicate effectively with a variety of audiences and for different purposes. |
| **Standard 5** | Students employ a wide range of strategies as they write and use different writing process elements appropriately to communicate with different audiences and for a variety of purposes. |
| **Standard 8** | Students use a variety of technological and informational resources (e.g. libraries, databases, computer networks, video) to gather and synthesize information and to create and communicate knowledge. |

**Performance Objectives**

*It is expected that students will:*

       Determine the center of gravity location of an aircraft.

       Explain how aircraft are designed for stability and control.

       Design and analyze an airfoil considering lift and drag.

       Use the lift and draft equations to calculate associated forces and conditions.

       Describe the requirements for a glider to remain stable in flight.

       Design and construct a glider that meets the design requirements provided by the instructor.

       Summarize test data to evaluate glider performance against design criteria.

**Assessment**

*Explanation*

       Students will describe the forces acting on an aircraft.

       Students will describe how aircraft surfaces are moved to control an aircraft in flight.

*Application*

       Students will determine the center of gravity location of an aircraft.

       Students will design an airfoil to meet a design constraint.

       Students will calculate atmospheric conditions.

       Students will explain how to identify the various factors that affect the lift and drag forces generated by an airfoil.

       Students will calculate aerodynamic forces using the lift and drag equations.

       Students will design and build a glider.

*Self-knowledge*

       Students will determine the information needed to solve a complex problem and locate credible information.

**Essential Questions**

1.     How are aircraft controlled in flight?

2.     How is lift created for an aircraft?

3.     What is essential for aircraft to fly?

4.     What are the real world solutions to the challenge of long distance or duration flight?

5.     What factors affect lift and drag?

**Key Terms**

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| **Term** | **Definition** |
| **Aileron** | Small-hinged sections on the outboard portion of a wing that are used to generate a rolling motion for an aircraft. |
| **Airfoil** | Any surface, such as a wing, which provides aerodynamic force when it interacts with a moving stream of air. |
| **Angle of Attack** | The angle formed by the wing chord line and the relative wind. |
| **Aspect Ratio** | The relationship between the length and width of a wing. |
| **Boundary Layer** | A thin layer of air next to the surface of an airfoil which shows a reduction in speed due to the air’s viscosity. |
| **Center of Gravity** | The common reference point for the three axes of the aircraft. |
| **Cockpit** | The space in the fuselage of a small airplane containing seats for the pilot, copilot, and sometimes passengers. |
| **Controllability** | The capability of an aircraft to respond to your flight inputs, especially with regard to attitude and flight path. |
| **Dihedral** | The mounting of wings so that the wingtips and higher than the wingroot. |
| **Drag** | Acts in the opposite direction of flight, opposes the forward-acting force of thrust, and limits the forward speed of the aircraft. |
| **Dynamic Stability** | Out of its own accord, an aircraft eventually returns to and remains at its equilibrium position over a period of time. |
| **Elevator** | A rear horizontal stabilizer that controls up and down or pitching motion of the aircraft nose. |
| **Empennage** | The tail assembly of an aircraft, including the horizontal and vertical stabilizers, elevators and rudder. |
| **Flaps** | Control surfaces attached to the trailing edge of the wing extending outward from the fuselage to the midpoint of each wing. Flaps can increase the lifting efficiency of the wing and decrease stall speed. |
| **Fuselage** | Houses the cabin, the cockpit and is a common attachment point for the other major components. |
| **Glider** | An aircraft that is designed to fly without an engine. |
| **Horizontal Stabilizer** | A structure that creates up and down forces at the tail to keep the fuselage aligned in pitch with the relative wind. The structure itself is horizontal while the forces it creates are vertical. |
| **High hypersonic** | Aircraft speeds between Mach 10 and 25. |
| **Hypersonic** | Aircraft speeds between Mach 5 and 10. |
| **Keel Effect** | The flat surfaces located behind the center of gravity tend to weathervane with the wind. |
| **Lapse Rate** | The rate at which temperature decreases with an increase in altitude. |
| **Lateral Axis** | The horizontal line that passes through the center of gravity of the aircraft, perpendicular to its flight path. |
| **Leading Edge** | The part of the airfoil that meets the airflow first. |
| **Lift** | The force that created by the effect of airflow as it passes over and under the wing. |
| **Longitudinal Axis** | A straight line parallel to the length of the fuselage but that runs through the aircraft’s center of gravity. |
| **M** | Mach. A decimal number representing the true airspeed relationship to the local speed of sound. |
| **Maneuverability** | Characteristic of the aircraft that permits you to maneuver it easily and allows it to withstand the stress resulting from the maneuver. |
| **Pitch** | Motion around the lateral axis caused by deflection in the elevator controlled by moving the yoke forward and aft. |
| **Powerplant** | Consists of both the engine and propeller in a small airplane. |
| **Stability** | Aircraft stability is the characteristic of an airplane in flight that causes it to return to a condition of equilibrium, or steady flight, after it is disturbed.  |
| **Stall** | Caused by the separation of airflow from the wing’s upper surface resulting in a rapid decrease in lift. |
| **Static Stability** | Forces and moments on the body caused by a disturbance tend initially to return the body toward its equilibrium position. |
| **Subsonic** | Aircraft speeds under Mach 1. |
| **Supersonic** | Aircraft speeds between Mach 1 and 5. |
| **Taper** | A reduction in the chord of a wing as measured from the root to the tip of the wing. |
| **Thrust** | Forward-acting force which opposes drag and propels the aircraft through the air. |
| **Trailing Edge** | The last point on an airfoil that interacts with the airflow around the wing. |
| **Reynolds Number** | The ratio of inertial forces to viscous forces. |
| **Roll** | Rolling motion about the longitudinal axis caused by ailerons deflecting in opposite directions and controlled by twisting the yoke. |
| **Rudder** | A rear vertical stabilizer that controls side-to-side or yawing motion of the aircraft nose. |
| **Vertical Axis** | A straight line through the center of gravity of the aircraft and at 90° to lateral and longitudinal axis. |
| **Vertical Stabilizer** | A structure that creates left to right forces to keep the fuselage aligned in yaw with the relative wind. The structure itself is vertical while the forces it creates are horizontal. |
| **Wash In/Wash Out** | A built in twist in the wing so that the trailing edge at the wingtip is raised (Wash out) or lowered (Wash in). This significantly affects the slow flight and stall characteristics of the wing. |
| **Weight** | A force caused by the gravitational attraction of the Earth. |
| **Wing** | Generates the lifting force that helps the airplane fly when air flows around it. |
| **Wing Planform** | The outline shape of a wing when viewed from above. |
| **Wing Span** | The distance from wing tip to wing tip of a wing planform. |
| **Yaw** | The movement about the vertical axis produced by the rudder and controlled by pedals. |

**Day-by-Day Plans**

*Time: 14 days*

**Day 1:**

       The teacher will present **Aircraft Control Surfaces and Components.ppt** while students take notes in their journal.

       The teacher will distribute and explain **Activity 1.2.1 Aircraft Control Surfaces and Components**.

       The students will complete Activity 1.2.1 Aircraft Control Surfaces and Components.

       The teacher will evaluate Activity 1.2.1 Aircraft Control Surfaces and Components using **Activity 1.2.1 Aircraft Control Surfaces and Components Answer Key**.

       The teacher will present **Forces of Flight and Stability.ppt** while students take notes in their journal.

       The teacher will distribute **Activity 1.2.2 Center of Gravity**.

       Students will completeActivity 1.2.2 Center of Gravity.

**Day 2:**

       The teacher will present **Atmosphere.ppt** while students take notes in their journal.

       The teacher will introduce and distribute **Activity 1.2.4 Atmospheric Conditions**.

       Students will complete Activity 1.2.4 Atmospheric Conditions.

       The teacher will present **Aerodynamic Forces.ppt** while students take notes in their journal.

       Students will complete **Activity 1.2.5 Aerodynamic Forces**.

**Day3-4:**

       The teacher will present **Flight Simulator.ppt**

       The teacher will introduce **Activity Student Pilot. n**.

       Students will completeActivity Student Pilot.

**Day5-7:**

       The teacher will present **Airfoil Simulation.ppt**.

       The teacher will introduce and distribute **Activity 1.2.6 Airfoil Simulation**.

       Students will completeActivity 1.2.6 Airfoil Simulation.

       The teacher will present **Airfoil Construction.ppt**.

       The teacher will introduce and distribute **Activity 1.2.7 Airfoil Construction**.

       Students will complete Activity 1.2.7 Airfoil Construction.

       The teacher will present **Wind Tunnel Testing.ppt** while students take notes in their journal.

       Students will complete **Activity 1.2.8 Airfoil Testing**.

**Day 8:**

       The teacher will present **Gliders in Flight.ppt** while students take notes in their journal. Discuss the fundamental principles controlling glider flight and stability and introduce the goal of developing a glider design for long distance flight.

       The teacher will present **Gliders AERY Software Intro.ppt** for interface, procedures, and output interpretation instructions.

       The teacher will distribute **Activity 1.2.9 Using AERY Software**.

       Students will complete Activity 1.2.9 Using AERY Software.

       The teacher will distribute **Project 1.2.10 Glider Design: Challenge One**.

        Students will complete Project 1.2.10 Glider Design: Challenge One.

**Day 9-10:**

       The teacher will distribute **Project 1.2.11 Glider Design: Challenge Two** and **Project 1.2.11a Glider Design Challenge Report**.

       Students will complete Project 1.2.11 Glider Design: Challenge Two.

       The teacher will distribute and explain **Problem 1.2.12 Glider Design: Long Distance Flight****,** **Project 1.2.12a Glider Design Research Funding Call for Phase One Proposals** and **Project 1.2.12b Glider Design: Research Journal Template**.

       The teacher will introduce students to the flight testing equipment and process flow chart for the project.

       Students will begin to work on glider design.

       Students will make daily engineering notebook entries using Project 1.2.12b Glider Design: Research Journal Template as a guide.

       Students will submit their Project 1.2.12a Glider Design Research Funding Call for Phase One Proposals for construction authorization.

**Day 11-14:**

       The teacher will present **Balsa Glider Construction.ppt** and lead students in a discussion about tools, materials, and construction techniques for glider construction.

       Students will build gliders.

       Students will continue to make daily engineering notebook entries using Project 1.2.12b Glider Design: Research Journal Template as a guide.

       The teacher will distribute **Project 1.2.13 Glider Design: Flight Test Data** and **Project 1.2.14 Glider Design: Competitive Flights**.

       The teacher will introduce the launch apparatus and flight testing data form and review evaluation rubric for the glider design lesson.

       The teacher will monitor and guide student progress.

       Students will build gliders.

       Students will make a Research Journal entry.

       The teacher will set up and demonstrate the launch equipment with procedures, and then monitor student collection of flight test data.

       Students will collect and summarize flight test data.

       Students will optimize glider designs based on preliminary flight test data.

       Students will make a Research Journal entry.

       The teacher will review **Project 1.2.14b Competitive Flights Rubric**with students.

       The teacher will demonstrate **Project 1.2.14a Glider Design: Competitive Flights Spreadsheet**.

       Students will perform competition flights.

       Students will enter data into the competition spreadsheet.

       Students will optimize glider designs based on competition flight data.

       Students will make a Research Journal entry.

       The teacher will monitor and guide student progress.

       Students will launch gliders and collect flight data.

       Students will make a Research Journal entry.

       The teacher will guide a class discussion focused on competition data and glider design elements.

       The teacher will distribute **Project 1.2.15 Glider Design: Phase Two Research Funding Request**.

       Students will summarize findings regarding optimal design for a long distance glider.

       Students will complete Project 1.2.15 Glider Design: Phase Two Research Funding Request.