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| **Lesson 2.2 Propulsion** |

**Preface**

Aircraft require a force to sustain flight. For example a glider uses upward rising air to increase its potential energy which it converts into lift by descending. Powered aircraft rely on internally generated thrust to sustain flight. Within the atmosphere an aircraft propulsion system uses air and fuel for the combustion process which then provides thrust. Beyond the atmosphere spacecraft produce thrust through a variety of methods since air is not available in the vacuum of space.

In the lesson students will explore various ways thrust is produced for aircraft and space craft. Students will also design, build and test their own model rockets.

**Concepts**

1.     Energy transformed between forms of energy produces propulsion.

2.     Newton’s Three Laws of Motion are central to the idea of propulsion.

3.     Engines vary in terms of efficiency, speed, and altitude.

4.     Air and fuel are used for combustion.

5.     Engine configuration impacts flight performance.

6.     Rocket engines produce thrust through rapid expansion of gases.

**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 5:  Students will develop an understanding of the effects of** **technology on the environment.** |
| **BM H:** | When new technologies are developed to reduce the use of resources, considerations of trade-offs are important.   |
| **BM I:** | With the aid of technology, various aspects of the environment can be monitored to provide information for decision-making.  |
| **BM J:** | The alignment of technological processes with natural processes maximizes performance and reduces negative impacts on the environment.  |
| **BM K:** | Humans devise technologies to reduce the negative consequences of other technologies.  |
| **BM L:** | Decisions regarding the implementation of technologies involve the weighing of tradeoffs between predicted positive and negative effects on the environment. |
| **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.   |
| **BM J:** | A number of different factors, such as advertising, the strength of the economy, the goals of a company and the latest fads contribute to shaping the design of and demand for various technologies. |
| **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 J:** | Early in the history of technology, the development of many tools and machines was based not on scientific knowledge but on technological know-how.  |
| **BM N:** | The Industrial Revolution saw the development of continuous manufacturing, sophisticated transportation and communication systems, advanced construction practices, and improved education and leisure time. |
| **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 M:** | Diagnose a system that is malfunctioning and use tools, materials, machines, and knowledge to repair it. |
| **BM N:** | Troubleshoot, analyze, and maintain systems to ensure safe and proper function and precision.  |
| **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 K:** | Synthesize data, analyze trends, and draw conclusions regarding the effect of technology on the individual, society, and environment.   |
| **BM L:** | Use assessment techniques, such as trend analysis and experimentation to make decisions about the future development of technology.   |
| **BM M:** | Design forecasting to evaluate the results of altering natural systems. |
| **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.   |
| **BM L:** | It is possible to build an engine to perform work that does not exhaust thermal energy to the surroundings.   |
| **BM M:** | Energy resources can be renewable or nonrenewable. |
| **BM N:** | Power systems must have a source of energy, a process, and loads. |
| **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 O:** | Communication systems are made up of source, encoder, transmitter, receiver, decoder, storage, retrieval, and destination. |
| **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.  |
| **BM K:** | Intermodalism is the use of different modes of transportation, such as highways, railways, and waterways as part of an interconnected system that can move people and goods easily from one mode to another.   |
| **BM L:** | Transportation services and methods have led to a population that is regularly on the move.   |
| **BM M:** | The design of intelligent and non-intelligent transportation systems depends on many processes and innovative techniques. |
| **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 M:** | Materials have different qualities and may be classified as natural, synthetic, or mixed.   |
| **BM N:** | Durable goods are designed to operate for a long period of time, while non-durable goods are designed to operate for a short period of time.   |
| **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.   |
| **BM Q:** | Chemical technologies provide a means for humans to alter or modify materials and to produce chemical products.   |
| **BM R:** | Marketing involves establishing a product’s identity, conducting research on its potential, advertising it, distributing it, and selling it. |
| **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 L:** | The design of structures includes a number of requirements.   |
| **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**

        **Evolution and equilibrium**

        **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

        **Structure and properties of matter**

        **Chemical reactions**

        **Motions and forces**

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

        **Interactions of energy and matter**

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

        **Origin and evolution of the earth system**

        **Origin and evolution of the universe**

**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**

**Science in Personal and Social Perspectives Standard F:** As a result of activities in grades 9-12, all students should develop understanding of

        **Environmental quality**

        **Natural and human-induced hazards**

        **Science and technology in local, national, and global challenges**

**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**

        **Nature of scientific knowledge**

        **Historical perspectives**

***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. |
| **Data Analysis and Probability** | Instructional programs from pre-kindergarten through grade 12 should enable all students to formulate questions that can be addressed with data and collect, organize, and display relevant data to answer them; select and use appropriate statistical methods to analyze data; develop and evaluate inferences and predictions that are based on data; understand and apply basic concepts of probability. |
| **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 7** | Students conduct research on issues and interests by generating ideas and questions, and by posing problems. They gather, evaluate, and synthesize data from a variety of sources (e.g. print and non-print texts, artifacts, and people) to communicate their discoveries in ways that suit their purpose and audience. |
| **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:*

       Design an engine for an aircraft.

       Determine the thrust of an engine.

       Design an effective model rocket.

       Research and investigate rocket engines for use in a rocket.

       Test a model rocket to perform as predicted.

       Identify the main propulsion systems and the parts of a rocket engine.

       Compare the advantages and disadvantages of various rocket systems.

       Explain the rocket types used by various spacecraft.

       Explain how Newton’s three laws of motion relate to rocket propulsion.

**Assessment**

*Explanation*

       Students will describe the advantages and disadvantages of various rocket systems.

       Students will explain the rocket types used by various spacecraft.

       Students will explain the purpose of converging diverging nozzles in rocket and gas turbine systems.

*Interpretation*

       Students will use data collected from engine testing to predict flight performance.

       Students will analyze data collected to determine design effectiveness.

*Application*

       Students will design an engine to meet design criteria.

**Essential Questions**

1.     How does an airplane fly?

2.     How does an airplane produce thrust?

3.     If air is so thin, how does an airplane manage to push itself forward?

4.     How are a propeller and a jet engine so similar? How do they differ?

5.     Why do some airplanes have more than one engine?

**Key Terms**

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| **Term** | Definition |
| **Center of Pressure** | The point on the surface of an object about which the object’s surface area is centered. |
| **Compression Stroke** | The piston moves back towards the cylinder head. |
| **Exhaust Stroke** | Expels the burned gases from the chamber. |
| **Gas Turbine** | A device that create a hot exhaust gas which was passed through a nozzle to produce thrust. |
| **Intake stroke** | The piston moves away from the piston head on the intake stroke. |
| **Payload** | The cargo carried by a rocket. |
| **Power stroke** | When the spark plug fires and the compressed mixture is ignited to begin the power stroke. |
| **Propellant** | A mixture of fuel and oxidizer that burns to produce rocket thrust. |
| **Turbofan** | A turbojet engine that has a large ducted fan mounted on the shaft ahead of the compressor. |
| **Turbojet** | A type of gas turbine engine. |

**Day-by-Day Plans**

*Time:  21 days*

**Day 1-2:**

       The teacher will present **Concepts**, **Key Terms**, and **Essential Questions**, in order to provide a lesson overview.

       The teacher will present **Newton’s Laws.ppt** while students take notes in their journal.

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

       The teacher will distribute **Activity 2.2.2 Engine Simulator**.

       Students will complete **Activity 2.2.2 Engine Simulator**.

**Day 3-5:**

       Distribute the **Project 2.2.3 Turbine Engine Design**

       Students will complete the**Project 2.2.3 Turbine Engine Design**.

**Day 5-7:**

       The teacher will present **Rocket Components and Design.ppt**while students take notes in their journal. Note that instructions to construct a rocket using composite materials are available in **Lesson 2.2 Teacher Notes**.

       The teacher will distribute **Project 2.2.5 Rocket Design and Build**.

       Students will work on **Project 2.2.5 Rocket Design and Build**.

**Day 7-9:**

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

       The teacher will launch their rockets while gathering data for their **Project 2.2.6 Rocket Launch**.

**Day 10:**

       Students will complete the **Project 2.2.7 Rocket Performance Analysis**.

**Day 11:**

       Students will complete the **Activity 2.2.8 Max Velocity and Acceleration.**

**Day 12-18:**

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

       The teacher will distribute **Project 2.2.8 Space Propulsion**.

       Students will complete Project 2.2.8 Space Propulsion.

Day 19-21:

 The teacher will present the **Game Introduction.ppt** (see Teacher Notes) module 2.

 The teacher will distribute Race to Mars usernames and passwords.

 The students will work through the game intro, select a contract, and hire crewmembers for the spacecraft.

 Students complete Game Module 2: Vehicle Design.

 The teacher will explain and distribute Assignment 3: Breathe Easy from **Race2Mars\_HW\_PLTW**

 The teacher will present the **Game Introduction.ppt** (see Teacher Notes) module 3.

 The teacher will distribute Race to Mars usernames and passwords.

 The students will work through the game intro, select a contract, and hire crewmembers for the spacecraft.

 Students complete Game Module 3: Landing Systems in the game.