The Power Cycle – Intake Systems

Session Time: Three, 50-minute sessions

DESIRED RESULTS

ESSENTIAL UNDERSTANDINGS

A deep understanding of how an aircraft operates enables a pilot to fly the aircraft to its maximum capabilities in both normal and abnormal situations. (EU5)

ESSENTIAL QUESTIONS

1. Why do airplanes need mixture control and cars don't?
2. How can icing occur at temperatures above freezing?

LEARNING GOALS

Students Will Know

- Airplane engines need a mixture of fuel and air to operate
- The induction system mixes air and fuel in one of two main ways: through a carburetor or direct fuel injection
- Carburetors are subject to icing under certain operational and atmospheric conditions
- Each type of induction system has advantages and disadvantages

Students Will Be Able To

- *Apply* what they've learned about carburetor systems to predict and resolve performance problems in aircraft. (DOK-L4, DOK-L2)
- *Compare* the benefits and disadvantages of different types of induction systems. (DOK-L3)
- *Construct* a model of a venturi tube. (DOK-L3)

ASSESSMENT EVIDENCE

Warm-up
Students will watch a video reviewing how an internal combustion engine works. Then, they will hypothesize why a pilot might need to increase or decrease the amount of fuel in the fuel-air mixture at different times during a flight.

Formative Assessment
Students will label the parts and functions of a float-type carburetor and a fuel injection system.

Summative Assessment
Students will compare and contrast the components and operation of a carburetor system and a fuel-injection system by creating a Venn diagram.

LESSON PREPARATION

MATERIALS/RESOURCES

- The Power Cycle – Intake Systems Presentation
- The Power Cycle – Intake Systems Student Activity 1
- The Power Cycle – Intake Systems Student Activity 2
- The Power Cycle – Intake Systems Student Activity 3
- The Power Cycle – Intake Systems Teacher Notes 1
- The Power Cycle – Intake Systems Teacher Notes 2
- The Power Cycle – Intake Systems Teacher Notes 3

Venturi Model Activity (per group)

- Clear vinyl tubing 5/8" outside dimension, 1/2" inside dimension
- Two stainless steel adjustable hose clamps, 5/8" or larger
- Glass of water
- Screwdriver
- Coffee straw/stirrer (smallest straw you can find)
- Utility knife
- Ruler
- Awl or tool to create a hole in the tubing (as small as the straw)

LESSON SUMMARY

The lesson begins with a review of the internal combustion engine. Students will hypothesize why a pilot might need to adjust the flow of fuel to the engine. Students will then learn about aircraft intake or induction systems, including their purpose and how they work. This lesson will include an explanation of the types of induction systems as well as a discussion of their individual components.

Students will begin their in-depth look at induction systems with carburetor systems. Students will be introduced to the types of carburetion systems, float-type and pressure-type, and then watch a video detailing how a carburetor works. Students will then learn how pilots control the fuel-air mixture via the mixture control in the cockpit. They will also learn basic terminology associated with this process and walk through an example scenario for leaning (i.e., reducing the amount of fuel in) the mixture in flight. A second video will demonstrate the process of mixture leaning.

After the basic functionality concepts are introduced, students will learn about carburetor icing and its indications, as well as how to prevent or remove carburetor ice using carburetor heat. The students will then learn about indicators and instruments associated with these systems, such as the carburetor air temperature gauge and the outside air temperature gauge.
Finally, the students will learn about fuel injection systems and their components, including how they work and their advantages and disadvantages.

To conclude the lesson, the students will label the parts of a carburetor and a fuel injection system. They will then construct a model venturi, a key part of a carburetor, and finally, complete a Venn diagram showing the similarities and differences between a carburetor system and a fuel injection system.

BACKGROUND

As discussed in Lesson 1 of this unit, internal combustion engines work by burning a mixture of fuel and air in the cylinders. As the mixture burns, the expansion of the resulting gases pushes the piston down, which turns a crankshaft that is connected to a propeller.

Students should recall that the engines commonly used in light aircraft are four-stroke reciprocating engines. The four strokes are intake, compression, combustion or power, and exhaust. During the intake stroke, the piston moves toward the bottom of the cylinder, creating an area of low pressure above it, which pulls the air or fuel-air mixture into the cylinder.

It is this intake process, also known as induction, that is the focus of this lesson.

There are two basic basic induction systems for internal combustion engines, defined by where fuel is added to the process. In a carbureted engine the fuel is mixed with the air in a device, the carburetor, before being sent into the cylinder. In a fuel injected engine, fuel is mixed with the air in the cylinder itself a moment before combustion.

Each system has its advantages and disadvantages, which will be covered in this lesson, but the most recent engine designs are fuel injected due to the greater efficiency and power that is possible with that system.

It's worth noting that in addition to carburetors or fuel injectors, some aircraft engines use forced induction systems, such as turbochargers and superchargers, to increase pressure and engine power output. Forced induction systems will be addressed in a later lesson in this unit.

MISCONCEPTIONS

Students may think that, because there is no visible mixture control in an automobile engine, the ratio of fuel to air is unimportant, or left to chance. While it is true that, because most automobiles operate at a relatively constant altitude when compared to aircraft, mixture control is less critical in an automobile, it can't be disregarded. In modern, fuel injected automobile engines, a computer and attached sensors measure air density and other factors and inject an appropriate amount of fuel based on conditions. In other words, the mixture control is automatic. Such controls are one of the main reasons that newer cars are more fuel efficient than older ones.

In older, carbureted automobile engines, mechanics can adjust the mixture by turning screws located on the carburetor. Such adjustments are necessary for these cars to operate efficiently in high altitude areas such as Denver.

DIFFERENTIATION

To support student comprehension in the **EXPLORE** section, create learning centers that allow students to learn about the two types of induction systems, carburetor and fuel injection. Provide students with material that helps them gain familiarity with these systems, including presentation material, videos, and handbooks. Follow-up with a whole group discussion comparing the benefits and disadvantages of the induction systems.

LEARNING PLAN

ENGAGE

Teacher Material: The Power Cycle – Intake Systems Presentation

Slides 1-2: Introduce the topic and learning objectives of the lesson.

Slide 3: Conduct the **Warm-Up**.

Warm-Up

Remind students that, for an internal combustion engine to work, a mixture of fuel and air must be delivered to the combustion chamber. The mixture has to fall with within specific ratios of air to fuel, called the stoichiometric ratio. The ideal stoichiometric ratio is one in which all available oxygen and all available fuel are consumed in combustion. Watch this video to learn about the required makeup of the fuel air mixture.

- "How to Calculate Stoichiometric Air Fuel Ratio" (Length 1:43)
  http://video.link/w/qBsg

Explain that in this lesson, students will focus on the first phase of the internal combustion cycle, the intake phase. In particular, students will consider how pilots manipulate the amount of fuel in the fuel-air mixture at different times during flight. Ask students:

- Based on what you know about air density, will altitude affect the ideal ratio of air to fuel?
- Based on the engines you've learned about in this unit, which parts of the fuel-air mixture do you think the pilot can control? (Fuel quantity, air quantity, both?)
- How might the pilot influence these factors?
- What happens if there's too much or too little fuel in the mixture? Air?

Students will learn the answers to these questions during the lesson; for now, simply record their ideas on the board. If students struggle to answer the questions, remind them that as an airplane gains or loses altitude, air density changes, which means the engine may contain more or less air at different times during flight.

EXPLORE

Teacher Materials: The Power Cycle – Intake Systems Presentation, The Power Cycle – Intake Systems Teacher Notes 1
Student Material: The Power Cycle – Intake Systems Student Activity 1

Slide 4: The purpose of the induction system is to bring in outside air, mix it with fuel, and then deliver this fuel-air mixture to the cylinders where combustion occurs. There is an intake port on the front of the engine cowling where the outside air enters the induction system. This port contains an air filter, which prevents dust and other foreign particles from entering the engine. Since there may be occasions when this air filter becomes clogged, an alternative source of air must be available. The alternative air source may function automatically, or be manually operated by the pilot.

Slide 5: The two most commonly used induction systems in small piston aircraft engines are the carburetor system and the fuel injection system. The fundamental difference between these systems is where the fuel and air are mixed. A carburetor mixes the fuel and air in the carburetor before sending the mixture to the intake manifold. A fuel injection system delivers the fuel and air directly into each cylinder where it is mixed.

Slide 6: There are two types of aircraft carburetors: float-type carburetors and pressure-type carburetors. The more common of the two carburetor types is the float-type carburetor. This type of carburetor uses differential air pressure to force fuel out of the float chamber (fuel reservoir) in the carburetor. This lesson will focus on float-type carburetors. The second type of carburetor is the pressure-type carburetor, which delivers fuel under pressure by use of an engine-driven or electric fuel pump. Pressure-type carburetors are not usually found on small aircraft engines. The basic difference between a float-type and a pressure-type carburetor is the method of delivering fuel.

Use this video as an introduction to how a float-type carburetor works.

- "How a Carburetor Works" (Length: 3:18)

  http://video.link/w/DO4f

Slides 7-9: Show students the first slide to give them an overview of the design of a float-type carburetor. Explain that fuel flows into the carburetor where it is held in a reservoir called a float chamber. Point out that the float regulates the flow of fuel into the float chamber the same way the float in a toilet tank regulates the flow of water.

Attached to this float is a needle that opens and closes a hole at the bottom of the carburetor bowl. This needle, which is controlled by the level of fuel in the float chamber itself, regulates the amount of fuel entering the carburetor. When the fuel in the chamber forces the float to rise, the needle valve restricts the fuel opening and shuts off the fuel flow to the carburetor. This valve opens again when the engine requires additional fuel.

Outside air enters the induction system through an air intake, usually located on the front part of the engine cowling. This outside air flows through an air filter, then into the air inlet of the carburetor. Inside the carburetor, this filtered air flows through a narrow throat in the body of the carburetor called a venturi. As the air flows through the venturi, a low-pressure area is created, which forces fuel through the fuel discharge nozzle located at the carburetor throat. The fuel that is drawn into this fast-moving, low-pressure airstream vaporizes, resulting in a fuel-air mixture that flows into the intake manifold and then into the cylinder, where it is ignited and burned.

The device that regulates the flow of the fuel-air mixture to the cylinders is called a throttle valve. The throttle valve is a butterfly-type valve and, is directly controlled by the throttle in the flight deck, which is operated by the pilot.

After walking students through this overview, use slides 8 and 9 to point out specific features of the carburetor and what function each serves.

A float-type carburetor like the ones commonly found in light aircraft has the following key components:

- Air bleed - The air bleed allows air to be mixed with fuel being drawn out of the discharge nozzle to decrease fuel density and promote fuel vaporization.
- Float chamber - Fuel level is maintained by a float-type device.
- Mixture needle - The mixture needle controls fuel to the discharge nozzle. Mixture needle position can be adjusted using the mixture control.
- Fuel inlet - Fuel is received into the carburetor through the fuel inlet.
- Fuel-air mixture - The blend of fuel and air is routed to the combustion chambers to be burned.
- Throttle valve - The flow of the fuel-air mixture is controlled by the throttle valve. The throttle valve is adjusted from the flight deck by the throttle.
- Venturi - The shape of the venturi creates an area of low pressure.
- Air inlet - Air enters the carburetor through the air inlet.
- Discharge nozzle - Fuel is forced through the discharge nozzle into the venturi by greater atmospheric pressure in the float chamber.

Slide 10: Remind students of Bernoulli's principle, which states that the pressure of a moving fluid (gas or liquid) varies with its velocity. As the velocity of a moving fluid increases, the pressure within the fluid decreases. This is an important principle that may be observed in many aviation applications, including the venturi tube, which is an essential part of a carburetor.

Teaching Tips

You can quickly demonstrate Bernoulli's principle in the classroom by holding a piece of paper by the edge, placing the paper just below your bottom lip, and blowing over the top of the paper. The paper will rise because of low pressure created by the increase in the speed of the air above the paper.

A venturi is a tube that has an inlet and an outlet of the same size (diameter) and which narrows in the middle. This is the constriction point, or throat. The liquid flows into the tube. As it reaches the throat, it speeds up and its pressure drops.

In a carburetor, the fluid flowing through the venturi is a mixture of fuel and air. The decrease in pressure at the throat of the venturi, pulls the fuel and air into the carburetor and causes the fuel to vaporize.

Slide 11: Working in small groups, students will build a model venturi using clear plastic tubing, a straw, and a cup of water. In this activity, students will see how constricting the flow of air in a venturi tube creates low pressure that can be used to move fluids, in this case moving water from the cup into the tube. Provide each group of students with a copy of **The Power Cycle – Intake Systems Student Activity 1**. Detailed instructions and sample responses are provided in **The Power Cycle – Intake Systems Teacher Notes 1**. Once students have built and tested their venturi tubes, have them complete the activity by answering the questions explaining what they observed.

EXPLAIN

Teacher Materials: The Power Cycle – Intake Systems Presentation, The Power Cycle – Intake Systems Teacher Notes 2
Student Material: The Power Cycle – Intake Systems Student Activity 2

Slide 12: Float-type carburetors have several disadvantages. The main disadvantage is the tendency for ice to form inside the system. This is referred to as carburetor icing or "carb ice." Another disadvantage of the float-type carburetor is that it does not function well during abrupt aircraft maneuvers as the non-pressurized fuel chamber may not remain full. Also, because of the inefficient manner in which the fuel and air are combined, carburetor systems are generally less fuel-efficient than fuel injection systems. Finally, the float-type carburetor does not work well with high performance engines due to low mixing pressures causing incomplete fuel vaporization and difficulty discharging fuel into some types of superchargers.

Slides 13-14: Due to its design, ice can form inside the carburetor. As this carburetor ice builds, it restricts the normal flow of the fuel-air mixture to the engine, causing a reduction in power as the engine is "starved" of its needed fuel. If the situation is not corrected, the engine may stop entirely. The most common locations for ice to form inside the carburetor are around the throttle valve and the venturi throat.

Carburetor ice forms due to fuel vaporization and the decrease in air pressure in the venturi, which causes a temperature drop of as much as 70°F in the carburetor. Since water vapor is present in the air as it passes through the carburetor, if the internal temperatures are at or below freezing, ice may form on the surfaces of the carburetor and the throttle valve.

Carburetor ice can form over a wide range of outside air temperatures (OAT) and relative humidities. It is most likely to occur when OAT is below 70°F and the relative humidity is above 80%. However, carburetor icing has been known to form with OAT as high as 100°F and with a relative humidity of only 50%.

It should be noted that carburetor icing can form at any time, in any phase of flight, but it is especially dangerous when using reduced power during a descent because the indications may go unnoticed until power is added. Carb ice is also especially serious when it occurs on takeoff or initial climb, when full power is needed to clear obstacles.

The classic indications of carburetor ice are reduced power and a rough running engine. In an aircraft with a fixed-pitch propeller, the first indication of carburetor ice is a decrease in engine RPM, which may or may not be followed by engine roughness. In an aircraft with a constant-speed propeller, the first sign of carburetor icing is usually a decrease in manifold pressure with no reduction in RPM.

Slide 15: To minimize the effects of carburetor ice, engines with float-type carburetors employ a carburetor heat system. This system is intended to keep the fuel-air mixture above the freezing point to prevent the formation of carburetor ice. Air is preheated prior to reaching the carburetor. Carb heat is used both to prevent the formation of ice and to melt ice that has already formed.

The carburetor heat system routes the outside air through a chamber or shroud surrounding the engine exhaust muffler, where the air is heated. Heated air is then delivered to the carburetor; a carburetor heat valve regulates the flow of heated air to the carburetor. This valve is controlled by the carburetor heat control knob, located inside the cockpit.

The use of the carburetor heat system is quite simple. Anytime the conditions are conducive to carburetor icing during flight, full carburetor heat should be applied immediately; the control knob should be left in the “on” position until the pilot is certain that the possibility of icing no longer exists. Since the carburetor heat system uses the heat of the engine exhaust to warm the air in the heat shroud, it is less effective and produces less heat when the throttle is closed for extended periods during flight. A good example of this is long, power-off glides during descent. When the engine cools, the vaporization of the fuel is less complete than when the engine is warm. This increases the probability of carburetor icing. To prevent this, periodically and smoothly open the throttle for a few seconds during a descent to keep the engine warm. This allows the carburetor heater to provide enough heat to prevent icing.

The use of carburetor heat decreases engine performance; since the heated air is less dense than the outside air, applying carburetor heat will enrich the fuel mixture. Because of this, carburetor heat should not be used when full power is needed, such as during takeoff or during a go-around.

Slide 16: There are two devices that assist the pilot in determining potential icing conditions. They are the carburetor air temperature gauge and the outside air temperature gauge (OAT).

A carburetor air temperature gauge may be installed in the airplane to help detect carburetor icing conditions. The gauge is marked with a yellow arc between 15°C and +5°C. The yellow arc indicates the carburetor temperature range where carburetor icing can occur. A placard on the gauge reads, “Keep needle out of yellow arc during possible icing conditions.” Should the needle move into the yellow arc during potential icing conditions or if there is an unexpected drop in RPM, the pilot should apply full carburetor heat. It should be noted that this gauge is not common in aircraft.

Slide 17: The outside air temperature gauge can be used in conjunction with an OAT/relative humidity chart that shows potential carburetor icing conditions. Caution should be used when operating in areas identified in the chart as icing risks; the use of carburetor heat is advisable.

Slide 18: A fuel injection system differs from a carburetor system in that fuel is injected directly into the cylinders where it mixes with air. The air intake system for a fuel injection system is similar to that used in a carburetor system.

There are six basic components to a fuel injection system: an engine-driven fuel pump, a fuel-air control unit, a fuel manifold (or distributor), discharge nozzles, an auxiliary fuel pump, and fuel pressure/flow indicators. The engine-driven fuel pump provides fuel pressure to the fuel-air control unit after the engine is started. The fuel-air control unit basically replaces the carburetor. This unit provides fuel to the engine based upon mixture setting and throttle position. The fuel manifold then distributes the fuel to each individual discharge nozzle. The discharge nozzles, located in each cylinder head, inject the fuel directly into the cylinders. The auxiliary fuel pump provides pressurized fuel to the fuel-air control unit for starting the engine and in case of an emergency. The fuel pressure/flow indicators are cockpit instruments for monitoring the fuel pressure.

Slide 19: Several advantages of using fuel injection include a reduction in evaporative icing, better fuel flow, faster throttle response, precise control of mixture, better fuel distribution, and easier starts in cold weather. There are also a few disadvantages of using fuel injection; these include difficulty in starting a hot engine, vapor locks during ground operations in hot weather, and problems associated with restarting an engine that quits because of fuel starvation.

Although a fuel injection system is considered to be less susceptible to icing than a carburetor system, it is susceptible to impact icing. Impact icing occurs when ice forms on the exterior of an aircraft and blocks openings such as the primary air intake for the fuel injection system.

Slide 20: Complete the **Formative Assessment**.

Formative Assessment

Provide each student with a copy of **The Power Cycle – Intake Systems Student Activity 2** worksheet. Working individually, students will label the diagrams and turn in their work to the teacher. Correct responses are available in **The Power Cycle – Intake Systems Teacher Notes 2**.

[DOK 1; *match, label*, DOK 2; *interpret*]

EXTEND

Teacher Materials: The Power Cycle – Intake Systems Presentation, The Power Cycle – Intake Systems Teacher Notes 2
Student Material: The Power Cycle – Intake Systems Student Activity 2

Slides 21-22: One of the key functions of an aircraft induction system is to enable the pilot to adjust the fuel-air mixture for optimum engine performance under a wide range of conditions.

The fuel-air mixture ranges from the "full rich" to the "full lean" position. The full rich position represents the greatest amount of fuel introduced into the fuel-air mixture for a high air density, such as you would find at sea level. At lower air densitiessuch as when operating at high altitudesthe mixture control must be reduced to keep the engine operating efficiently. This is referred to as "leaning" the mixture. (Conversely, to "enrich" the mixture is to add more fuel to it.) As an aircraft climbs or descends, the amount of fuel going into the engine must be varied to compensate for the changes in air density.

For example, as an aircraft descends from high altitude, the fuel-air mixture must be enriched, or it will eventually become too lean. Conversely, when an aircraft reaches its cruising altitude, the mixture must be leaned for peak performance and efficiency. Failure to appropriately control the fuel-air mixture can result in several problems: if the mixture is too lean, the engine can quit from fuel starvation; if the mixture is too rich, the plane may experience engine roughness and spark plug fouling.

This fuel-air mixture within the induction system of an aircraft engine is controlled from the cockpit by a mixture control lever or knob, normally colored red. The pilot adjusts this lever or knob as needed throughout the flight.

Questions

As a class, discuss this question:

Why don't cars have a mixture control?
Airplanes move through a wide range of altitudes, temperatures, and air densities, which requires a similarly wide range of fuel in the fuel-air mixture. In contrast, automobiles operate over a much narrower range of altitudes, temperatures, and air densities. Even so, automobile engines do have a metered fuel-control system; in modern, fuel-injected automobiles, the fuel-air mixture is controlled automatically. In older carbureted engines, there is an adjustment mechanism on the carburetor itself.

Slide 23: After climbing to a higher cruising altitude, the mixture should be leaned to compensate for the decreased air density. Leaning the mixture decreases fuel flow. Consider this example of an accepted method of leaning the mixture for cruise flight:

Once established at your cruising altitude and in straight and level flight, set the RPM to the desired cruise power setting. In this example, let's assume you want a high-power, fast cruise profile of about 2,400 RPM. At this RPM setting, you would slowly pull the mixture-level lever back toward lean until the engine RPM begins to increase. Continue leaning slowly. When the RPM to begins to decrease or you experience slight engine roughness. enrich the mixture slightly until peak RPM is obtained.

Questions

As a class, discuss these questions:

Why does the engine RPM increase?
By leaning the mixture, you are removing unnecessary fuel from the fuel-air mixture; this allows the engine to operate more efficiently, resulting in increased performance.

Why does the engine run rough with further learning?
By further reducing the fuel available, you are starving the engine of the fuel it needs to run.

Slide 24: The following video demonstrates the in-flight leaning procedure.

- Video: "How to Lean the Mixture on Your Training Aircraft" (:57)
  http://video.link/w/Vmkg

Aircraft manufacturers provide detailed guidelines for mixture control use. Generally speaking, the mixture control should be in the FULL RICH position for all takeoffs, climbs, and landings, and for whenever full power is needed (such as during the possibility of a go around). Prior to beginning a descent, slowly advance the mixture control to the FULL RICH position. These procedures help prevent an engine from inadvertently operating with too lean of a mixture, causing it to run rough, overheat, or stop completely.

These are general guidelines. Always refer to the AFM (Aircraft Flight Manual) or POH (Pilot's Operating Handbook) to determine specific procedures for each particular aircraft type.

EVALUATE

Teacher Materials: The Power Cycle – Intake Systems Presentation, The Power Cycle – Intake Systems Teacher Notes 3
Student Material: The Power Cycle – Intake Systems Student Activity 3

Slides 25-44: Quiz students on questions from the Private Pilot Knowledge Test. If time is short, skip every other question

Slide 45: Conduct the **Summative Assessment**. Students will create Venn diagrams showing similarities and differences between carburetor systems and fuel injection systems. Their answers should reflect everything they've learned in this lesson, including advantages, disadvantages, components, and functions of each system.

Summative Assessment

Provide students **The Power Cycle – Intake Systems Student Activity 3**. Students may use the template provided as well as illustrations and drawings to demonstrate their understanding of the concepts of this lesson. They should complete the Venn diagram with information about each type of system. Encourage them to find as many unique traits as possible for each type of system and to look for similarities, in function, design, and components. Possible responses are found in **The Power Cycle – Intake Systems Teacher Notes 3**.

[DOK L4; *Create, Connect,* DOK L3; *Explain,* DOK L2; *Summarize*]

Summative Assessment Scoring Rubric

- Student follows instructions
- Answers show understanding of the concepts covered in the lesson
- Answers show in-depth thinking, including analysis or synthesis of lesson objectives

Points **Performance Levels**

9-10 The completed 3-column table shows a strong understanding of the lesson objectives. Commonalities and differences are correct and well organized in the table.

7-8 The completed 3-column table shows an adequate understanding of the lesson objectives with minor gaps in understanding.

5-6 The completed 3-column table shows a poor understanding of the lesson objectives with many gaps in understanding.

0-4 The 3-column table is disorganized or incomplete. Student work shows a lack of understanding of the objectives for this lesson.

STANDARDS ALIGNMENT

NGSS STANDARDS

Three-dimensional Learning

- **HS-PS3-5** - Develop and use a model of two objects interacting through electric or magnetic fields to illustrate the forces between objects and the changes in energy of the objects due to the interaction.
  - Science and Engineering Practices
    - Developing and Using Models
  - Disciplinary Core Ideas
    - PS3.C Relationship Between Energy and Forces
  - Crosscutting Concepts
    - Systems and System Models
    - Cause and Effect
- **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.
  - Science and Engineering Practices
    - Constructing Explanations and Designing Solutions
  - Disciplinary Core Ideas
    - ETS1.B: Developing Possible Solutions
  - Crosscutting Concepts

- None

COMMON CORE STATE STANDARDS

- **RST.9-10.2** - Determine the central ideas or conclusions of a text; trace the text's explanation or depiction of a complex process, phenomenon, or concept; provide an accurate summary of the text.
- **RST.9-10.4** - Determine the meaning of symbols, key terms, and other domain-specific words and phrases as they are used in a specific scientific or technical context relevant to grades 9-10 texts and topics.
- **WHST.9-10.6** - Use technology, including the Internet, to produce, publish, and update individual or shared writing products, taking advantage of technology's capacity to link to other information and to display information flexibly and dynamically.
- **WHST.9-10.8** - Gather relevant information from multiple authoritative print and digital sources, using advanced searches effectively; assess the usefulness of each source in answering the research question; integrate information into the text selectively to maintain the flow of ideas, avoiding plagiarism and following a standard format for citation.

REFERENCES

Pilot's Handbook of Aeronautical Knowledge: Pages 7-7 to 7-12
https://www.youtube.com/watch?v=9BYm0HnLGRU
https://www.aopa.org/training-and-safety/students/solo/special/intake-and-exhaust-systems
https://www.aopa.org/-/media/files/aopa/home/pilot-resources/asi/safety-briefs/sb09.pdf?la=en&hash=526443ED8798604D33A89490F116E9EE2C281F6C
https://www.youtube.com/watch?v=VFBNy5-B7nA
https://www.youtube.com/watch?v=rMi643NlX5Q
Cessna Model 172 and Skyhawk Owners Manual, Cessna Aircraft Company, 1969.