National Aeronautics and Space Administration

GRADES **K-12**

Wing Design

parts of an airplane

Aeronautics
Research
Mission
Directorate

Museum
in a
BOX
Series

www.nasa.gov


(Photo courtesy of NASA - www.nasaimages.org)

Wing Design

Lesson Overview

In this lesson, students will learn about forces, motion, and properties of objects and materials through the concepts of basic wing design. They will begin by exploring birds' wings and discovering the properties required for successful flight. Next they will move to basic aircraft wing shapes and finally, calculate some basic wing parameters.

Objectives

Students will:

1. Discover how the feathers on different varieties of birds relate to their ability to fly.
2. Learn how airplane wings are designed for specific tasks and situations.
3. Learn the basic math behind wing design.

Materials:

In the Box

Ostrich Feather

Turkey Feather

Provided by User

Ruler

GRADES **K-12** **Time Requirements:** 1 hour 10 minutes

Background

Wing Design

Wing design is constantly evolving. If you were to compare the wing of the Wright Flyer (Img. 1) with that of a modern aircraft, such as the Boeing 787 (Img. 2), the difference is remarkable. The number of lifting surfaces, shape, size and materials used all contribute to an aircraft's performance.


(Photo courtesy of Wikipedia, GNU Free Documentation License)

Img. 1 The 1903 Wright Flyer

Since the 1930's, NASA and its predecessor NACA have been on the forefront of wing design, developing the basic airfoil shapes airplane manufacturers have used ever since to provide the lift component that is vital to air travel.


(Photo courtesy of Boeing)

Img. 2 Boeing 787

Before a wing is designed, its mission has to be determined. What type of aircraft will this wing be attached to? Will it need to operate at high altitudes with thin atmospheres? Will it have to carry heavy loads? Will it need space to mount the engines? How much fuel will we want to store inside? How fast or agile will the aircraft need to be? The list of potential specifications is long and highly complex.

The same type of design challenges can be seen in nature with our feathered friends, the birds. While all birds have wings, not every bird can fly. Take the ostrich (Img. 3) for example. It is a large bird, weighing on average nearly 200 pounds, but its wings are short and its feathers are fluffy and undefined. No matter how hard it tries, the wing will never be able to produce enough lift for the ostrich to fly.


(Photo courtesy of Lost Tribe Media, Inc.)

Img. 3 An ostrich with folded wings

The seagull (Img. 4) on the other hand is a small bird, weighing barely 2 pounds, but has long, thin wings which are perfect for gliding on the coastal breezes. It needs airflow over the wing to work though, so in order to fly the bird has to first run forwards to increase the airflow over its wings, just as a plane would on the runway.

The robin (Img. 5) uses a very different style of wing. To avoid predators such as cats, it needs to be able to jump quickly into the air and does so using short, fast moving wings that provide lots of lift, but at the sacrifice of forward speed.

Lastly, some predatory birds, such as hawks, need the ability to fly quickly in order to catch their prey, but also need to carry the meal home to their offspring. To achieve this, they are able to fold their wings back while diving, giving them a fast, sleek appearance for the attack, but a wide, large wingspan for carrying heavy loads on the journey home.


((Photo courtesy of Arnold Paul, CC BY-SA 2.5 License)

Img. 4 A seagull in flight

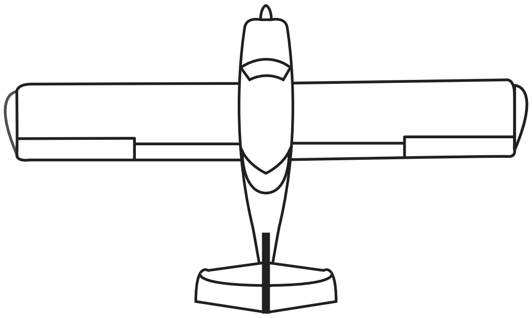

(Photo courtesy of Fauxpasgrapher, CC BY-NC-ND 3.0 License)

Img. 5 A robin in flight

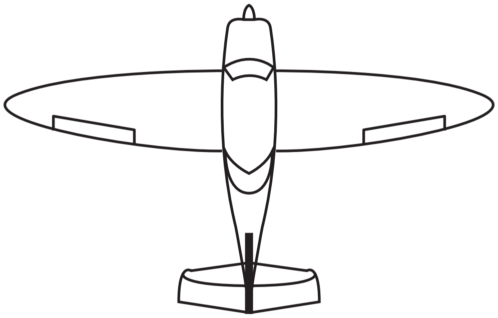
Compromises

As with everything in life there are compromises and this is no different with wing design. While each design works well, they all have limitations or restrictions making them suitable only for certain tasks.

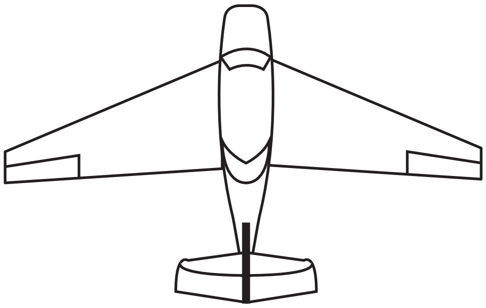
Rectangular Wing: The rectangular wing, sometimes referred to as the "Hershey Bar" wing in reference to the candy bar it resembles, is a good general purpose wing. It can carry a reasonable load and fly at a reasonable speed, but does nothing superbly well. It is ideal for personal aircraft as it is easy to control in the air as well as inexpensive to build and maintain.



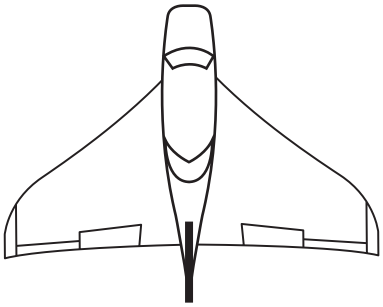
Elliptical Wing: The elliptical wing is similar to the rectangular wing and was common on tail-wheel aircraft produced in the 1930s and 40s. It excels however in use on gliders, where its long wingspan can capture the wind currents easily, providing lift without the need for a lot of forward momentum, or airspeed.



Swept Wing: The swept wing is the "go to" wing for jet powered aircraft. It needs more forward speed to produce lift than the rectangular wing, but produces much less drag in the process, meaning that the aircraft can fly faster. It also works well at the higher altitudes, which is where most jet aircraft fly.



Delta Wing: The delta wing advances the swept wing concept, pulling the wings even further back and creating even less drag. The downside to this however is that the aircraft has to fly extremely fast for this wing to be effective. This is why it's only found on supersonic aircraft (aircraft that fly faster than the speed of sound) such as fighter jets and the Space Shuttle orbiter. There were also two commercial passenger jets that used this wing design, the Russian TU-144 (Img. 6) and BOAC's Concorde (Img. 7), both of which could cruise at supersonic speeds.



(Photo courtesy of NASA)

Img. 6 A Russian TU-144 Supersonic Passenger Jet

(Photo courtesy of Henrysalome & Wikipedia (GNU Free Documentation License))

Img. 7 The BOAC Concorde Supersonic Passenger Jet

Wing Construction & Mathematics

The earliest wings were designed mostly through trial and error, using drawings and small scale models to test theories. Today though, we can precisely calculate a wing's performance before it ever leaves the ground. Below are some terms related to wings and the mathematics behind wing design.

Skin: The outer surface of the wing. Originally made of fabric, modern aircraft use aluminum or composite materials due to their lightweight and rust-resistant properties.

Ribs & Stringers: These make up the inner skeleton of the wing, providing rigidity and strength. While strength is necessary, it is also important that the wing can flex slightly while it flies. This flexibility allows it to absorb the stress caused by turbulence and hard landings.

Spar: The main center beam of the wing, designed to carry the structural loads and transfer them by attachment to the fuselage, or body, of the aircraft.

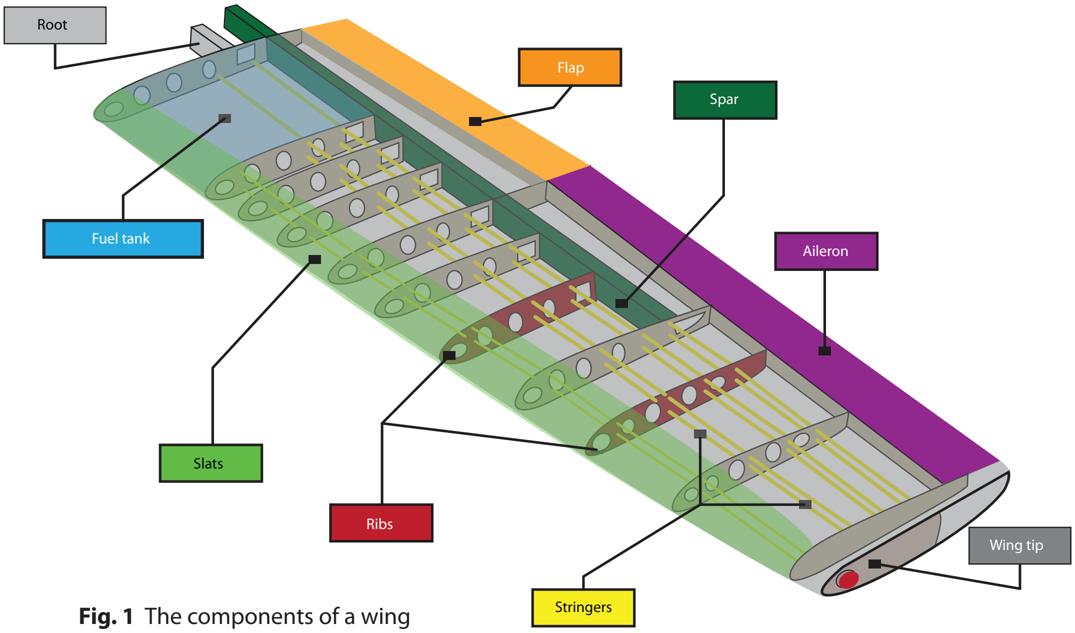


Fig. 1 The components of a wing

Fuel Tank: Commonly located in the wing, fuel can either be housed in its own tank or allowed to fill the cavities between the ribs. In addition to powering the engines, the fuel adds rigidity to the wing.

Flaps: Are a "high lift / high drag" device. Not only do they improve the lifting ability of the wing at slower speeds by changing the camber, or curvature of the wing, they also create more drag, meaning an aircraft can descend, or lose altitude faster, without gaining airspeed in the process.

Root: The wing root is the portion of the wing that attaches to the fuselage, or body of the aircraft.

Wing Tip: The wing tip is furthest from the fuselage and is typically where the navigation lights are mounted (a red light on the left, a green light on the right).

Slats: Another "high lift" device typically found on swept or delta wing aircraft. Slats are similar to the flaps except they are mounted on the leading edge of the wing. They also assist in changing the camber to improve lifting ability at slower speeds.

Wing Construction & Mathematics (cont.)

Aspect Ratio: The ratio of the wing's length to its chord line. A wing with a high aspect ratio will perform well at slow speeds and produce large quantities of lift, but at the expense of maneuverability and airspeed. A wing with a low aspect ratio on the other hand will have a sleek appearance and allow an aircraft to fly faster, or be more maneuverable.

Camber: The name given to the curvature of the upper or lower surfaces of the wing. A higher camber, or more curved surface, results in an aircraft that can fly at slower speeds while still generating sufficient lift for flight.

Chord Line: The theoretical line running from the leading edge of the wing to the trailing edge.

Leading Edge: The front edge of an aircraft's wing.

Trailing Edge: The rear edge of an aircraft's wing.

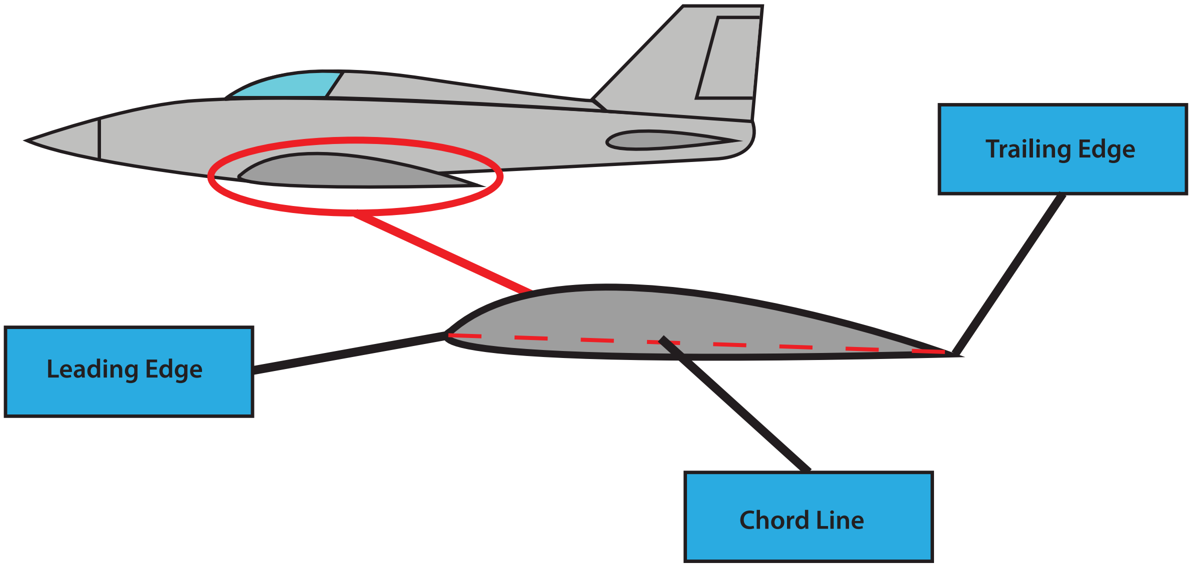


Fig. 2 Wing cross-section

For additional information on wing design and aerodynamics, please refer to the Museum In A Box lessons "Four Forces" and "Bernoulli Principle".

Activity 1 Avian Wing Comparison

GRADES K-12

Time Requirement: 20 minutes

Materials:

In the Box

Ostrich Feather
Turkey Feather

Provided by User

None

Worksheets

Avian Feather Comparison (Worksheet 1)

Reference Materials

Img. 8 Turkey
Img. 9 Ostrich

Key Terms:

None

Objective:

In this activity, students will discover how the feathers on different species of birds relate to their ability to fly.

Activity Overview:

Students will compare the feather characteristics of both flying and non-flying birds and determine how the design of the feather correlates to the ability of the bird to fly.

Activity:

1. **Begin by discussing with the students the Background information provided.**
2. **Pass around each of the feathers and their associated images while asking the students to determine which feather came from which bird.**
3. **Have the students list the characteristics of both the bird and the feather on their worksheets.**
   Note: Your students' answers may vary depending on the feathers included in the kit.
4. **Finally, have the students "flap" the feather in the air, using the same motion that a bird does flapping its wings.** Ask them to describe its reaction to the wind and record it on their worksheets.


(Photo courtesy of the United States Department of Agriculture)

Img. 8 Turkey


(Photo courtesy of Kwolana & Wikipedia – GNU Free Documentation License)

Img. 9 Ostrich

Discussion Points:

1. **Based upon your observations, why do you think the ostrich cannot fly, yet the turkey can?**
   It should be noticed that the ostrich feather isn't very good at catching the air. It has very little resistance, which means it cannot produce much lift. This is because of the large gaps between each hair on the wing. Also, the ostrich's wings are much shorter than the turkey's in comparison to the weight of the bird, meaning that the wing would have to work much harder in order to produce lift.

2. **What makes the turkey wing more efficient at flight?**
   The turkey wing has the appearance of a solid surface, just like an airplane's wing. This makes it much more efficient at producing lift. Also, the bone at the center of each feather is hollow, making it lighter and therefore requiring less energy for the bird to become airborne.

3. **Using what we have learned about bird wings, what can we infer about the wings of an airplane?**
   Generically speaking, long, thin wings that are light in weight will produce the most lift. It is important to note though that there is no single "best wing" solution. Each wing is designed specifically for the aircraft intended for use. While both turkeys and sparrows can fly, a turkey couldn't use a sparrow's wings to become airborne; they are simply too short to support the turkey's weight. The same is true for the wings of different aircraft. Activity Two discusses this in more detail.

NATIONAL SCIENCE STANDARDS K-4

SCIENCE AS INQUIRY

- Abilities necessary to do scientific inquiry
- Understanding about scientific inquiry

PHYSICAL SCIENCE

- Property of objects and materials

SCIENCE AND TECHNOLOGY

- Abilities of technological design
- Understanding about science and technology

NATIONAL SCIENCE STANDARDS 5-8

SCIENCE AS INQUIRY

- Abilities necessary to do scientific inquiry
- Understandings about scientific inquiry

PHYSICAL SCIENCE

- Properties and changes of properties in matter

SCIENCE AND TECHNOLOGY

- Abilities of technological design
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NATIONAL SCIENCE STANDARDS 9-12

SCIENCE AS INQUIRY

- Abilities necessary to do scientific inquiry
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PHYSICAL SCIENCE

- Structure and properties of matter
- Interactions of energy and matter

SCIENCE AND TECHNOLOGY

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Activity 2 Airplane Wing Design

GRADES K-12

Time Requirement: 20 minutes

Materials:

In the Box

None

Provided by User

None

Worksheets

Wing Designs (Worksheet 2)

Reference Materials

Img. 10 Lockheed Martin F-22 “Raptor”

Img. 11 Cessna T-37 “Tweet”

Img. 12 McDonald Douglas KC-10 “Extender”

Img. 13 Lockheed Martin/ NASA ER-2

4 Planform Silhouettes

Fig. 3 Lockheed Martin F-22 “Raptor”

Fig. 4 Cessna T-37 “Tweet”

Fig. 5 McDonald Douglas KC-10 “Extender”

Fig. 6 Lockheed Martin/ NASA ER-2

Key Terms:

None

Objective:

In this activity, students will learn how airplane wings are designed for specific tasks and situations.

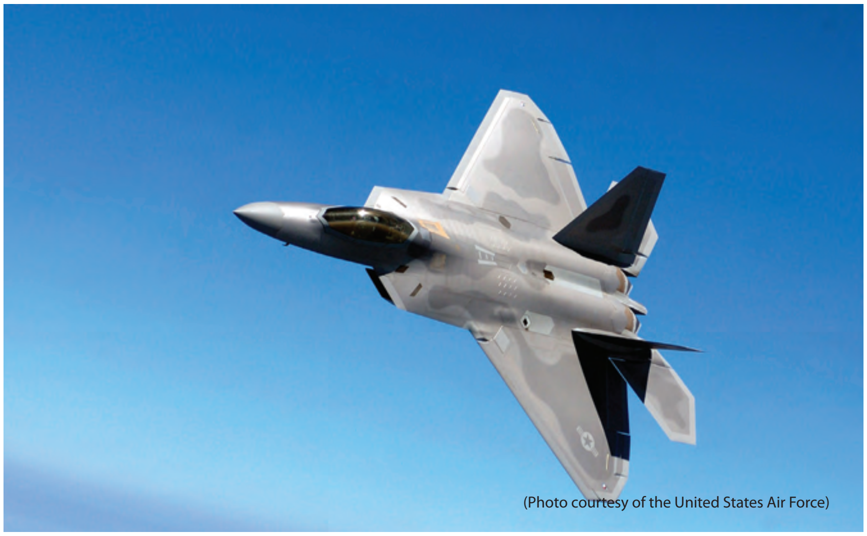
Activity Overview:

Students will compare the outline of a variety of airplane wings and determine how each can be used to perform specific tasks.

Activity:

1. **If you have not performed Activity 1 - Avian Wing Comparison, review the background information with the students prior to completing this activity.**

2. **Show the students each of the four images below and ask them to describe the type of plane and what purpose it serves.**
   - *Lockheed Martin F-22 “Raptor”: A fighter aircraft, designed to be fast and highly maneuverable.*
   - *Cessna T-37 “ Tweet”: A training aircraft for new military pilots.*
   - *McDonald Douglas KC-10 “ Extender”: A transport category aircraft, designed to carry heavy loads long distances.*
   - *Lockheed Martin/NASA ER-2: A very high-altitude surveillance plane.*



(Photo courtesy of the United States Air Force)

Img. 10 Lockheed Martin F-22 “Raptor”

(Photo courtesy of the United States Air Force)

Img. 11 Cessna T-37 "Tweet"

(Photo courtesy of the United States Air Force)

Img. 12 McDonald Douglas KC-10 "Extender"

(Photo courtesy of NASA)

Img. 13 Lockheed Martin/NASA ER-2

3. **Show the students each of the planform silhouettes and ask them to describe the type of plane it would likely be attached to and what purpose it might serve.**
   The silhouettes are in the same order as above. The purpose of this step is to highlight the specific differences in each wing so the students can correlate how a shape of wing is directly related to the type of aircraft it serves.

4. **Give each student a copy of the Wing Designs worksheet and discuss the differences between each design.**
   Rectangular Wing: *A rectangular wing is used on slower aircraft, typically training aircraft. It is somewhat maneuverable but allows for a high margin of pilot error. It also produces a large amount of lift so that the wing can be smaller in comparison to the body of the aircraft.*
   Elliptical Wing: *An elliptical wing is similar to the rectangular wing but is usually lighter and generates much more lift. It is often found on gliders and ultra-light aircraft.*
   Swept Wing: *Swept wings are usually found on jet aircraft. The thinner profile produces less drag, meaning it can fly at faster speeds. It is also much more maneuverable. These aircraft are less capable of flying at slow speeds however, so most swept wings are fitted with additional devices such as flaps or slats to assist in producing lift at low speeds.*
   Delta Wing: *The delta wing is used on very high speed (supersonic) aircraft, which are extremely maneuverable but much harder to control at slower speeds. As with the swept wing, they are also fitted with additional components to assist at slower speeds.*

Discussion Points:

1. **If you had to design a wing for an airplane, what are some of the questions you might ask?**
   While this question is very vague, it is designed to elicit further discussion on the factors behind wing design. For example, is the aircraft required to be fast and maneuverable, or does it have to carry a lot of weight? Is it being operated by skilled pilots or by newer, less experienced ones? Refer to the Background information for additional insight.

2. **Why is there not one "standard" wing that will work in all cases?**
   An unfortunate part of wing design is that what makes one wing great in certain areas makes it terrible in others. For example, the delta wing is extremely maneuverable, allowing the plane to perform quick, tight turns, but because it is so short, it requires a much higher airspeed to work. This prohibits it from being used on slower, propeller powered aircraft. The rectangular wing could work on all aircraft, but because of its size and shape, would restrict the speed at which an aircraft could travel. This makes it a poor choice for jet aircraft, which are designed to operate at much higher speeds.

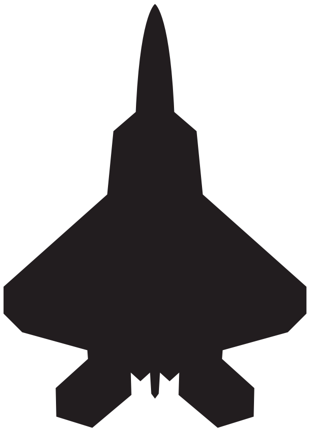


Fig. 3 Lockheed Martin F-22 “Raptor” Planform Silhouette

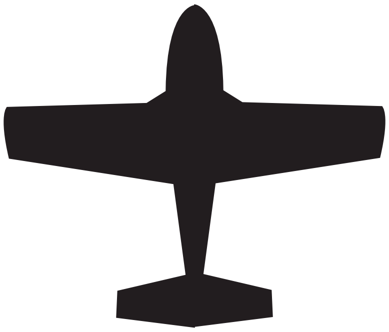


Fig. 4 Cessna T-37 “Tweet” Planform Silhouette

Fig. 5 McDonald Douglas KC-10 “Extender” Planform Silhouette

Fig. 6 Lockheed Martin/NASA ER-2 Planform Silhouette

NATIONAL SCIENCE STANDARDS K-4

SCIENCE AS INQUIRY

- Abilities necessary to do scientific inquiry
- Understanding about scientific inquiry

PHYSICAL SCIENCE

- Property of objects and materials

SCIENCE AND TECHNOLOGY

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NATIONAL SCIENCE STANDARDS 5-8

SCIENCE AS INQUIRY

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PHYSICAL SCIENCE

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NATIONAL SCIENCE STANDARDS 9-12

SCIENCE AS INQUIRY

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PHYSICAL SCIENCE

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- Interactions of energy and matter

SCIENCE AND TECHNOLOGY

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Activity 3 Wing Math

GRADES 9-12

Time Requirement: 30 minutes

Materials:

In the Box

None

Provided by User

Metric ruler

Worksheets

Wing Math
(Worksheet 3)

Reference Materials

None

Key Terms:

None

Objective:

In this activity, students will be exposed to and practice some of the math skills used in wing design.

Activity Overview:

Students will calculate the surface area, chord and aspect ratio of different wings to determine how they relate to the speed, maneuverability and performance of a wing.

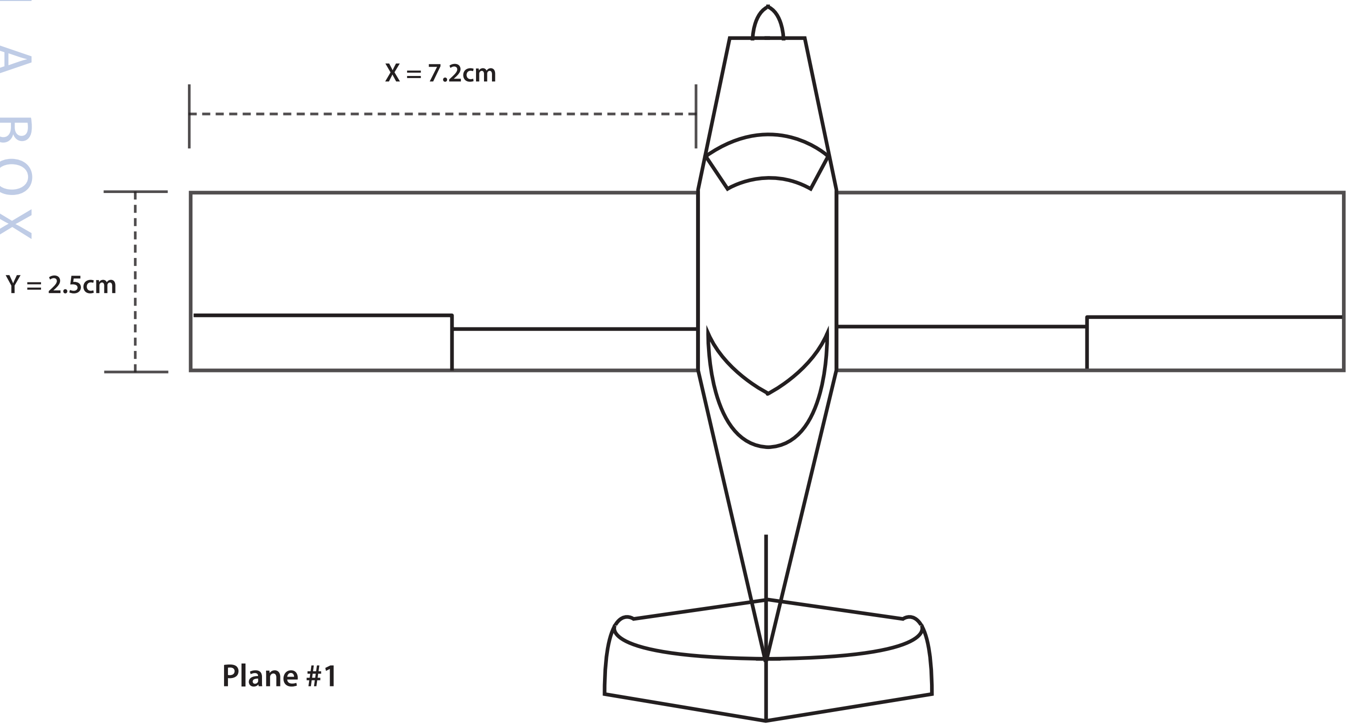
Activity:

1. **If necessary, complete Activity 2 – Wing Design with the students prior to completing this activity.** This will provide a better understanding of how wings are designed.

2. **Using the Wing Math worksheet, work through the first problem with your students.** Students should use a ruler to measure lines as needed.

$$\text{Aspect Ratio} = \frac{\text{Mean Chord}}{\text{Length}}$$

Surface Area of a Rectangle = Length x Height



Plane #1

a. **Calculate the surface area of one wing.**
   Multiply the length by the height.

   Surface Area = 7.2cm • 2.5cm = 18cm

b. **Calculate the length of the mean chord.**
   The mean chord is equal to the height of the wing.

   Mean Chord = 2.5cm

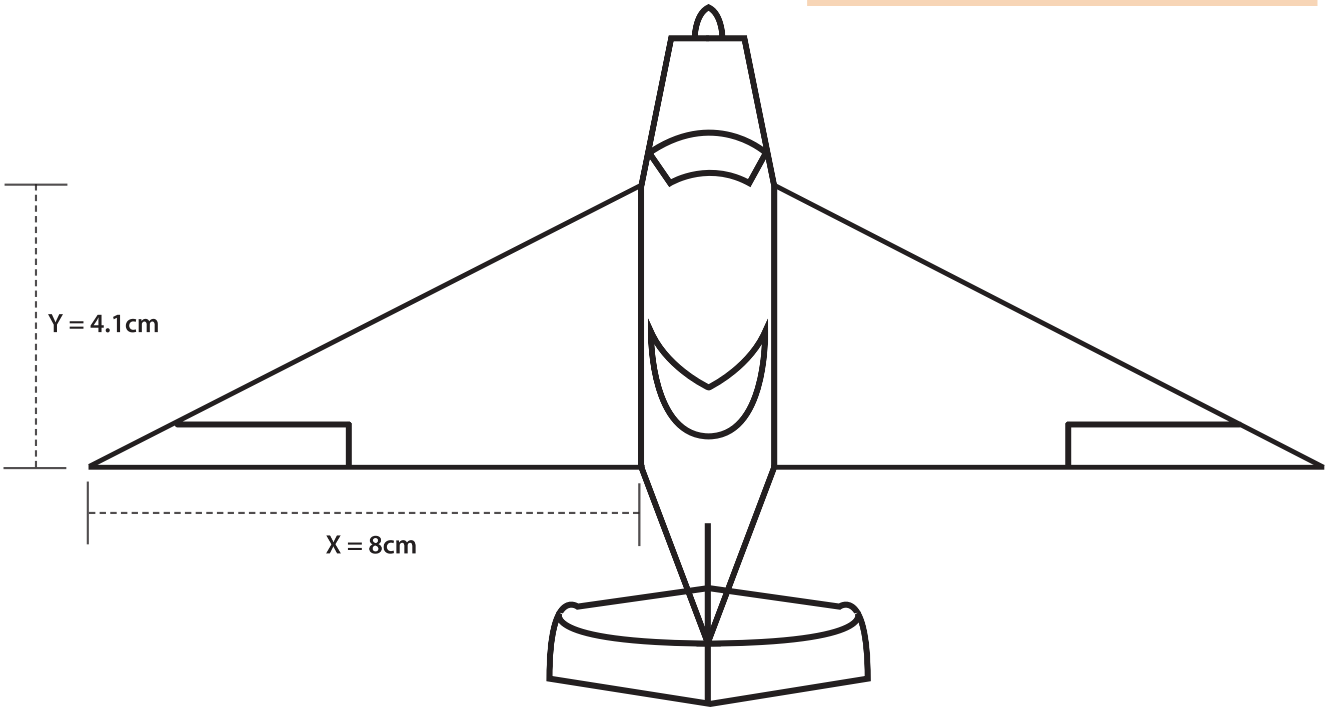
c. **Calculate the wing's aspect ratio.**
   Divide the mean chord by the length.

   $$\text{Aspect Ratio} = \frac{2.5\text{cm}}{7.2\text{cm}} = 0.35$$

3. **Have the students complete the remaining problems on the worksheet individually or in groups.**

$$\text{Aspect Ratio} = \frac{\text{Mean Chord}}{\text{Length}}$$

$$\text{Surface Area of a Right Triangle} = \frac{1}{2}(\text{Length x Height})$$



Plane #2

a. **Calculate the surface area of one wing.**

Multiply the length by the height, then divide by 2.

$$\text{Surface Area} = \frac{1}{2}(8\text{cm} \cdot 4.1\text{cm}) = 16.4\text{cm}$$

b. **Calculate the length of the mean chord.**

The mean chord is equal to one half of the height of the wing.

Mean Chord = 2.05cm

c. **Calculate the wing's aspect ratio.**

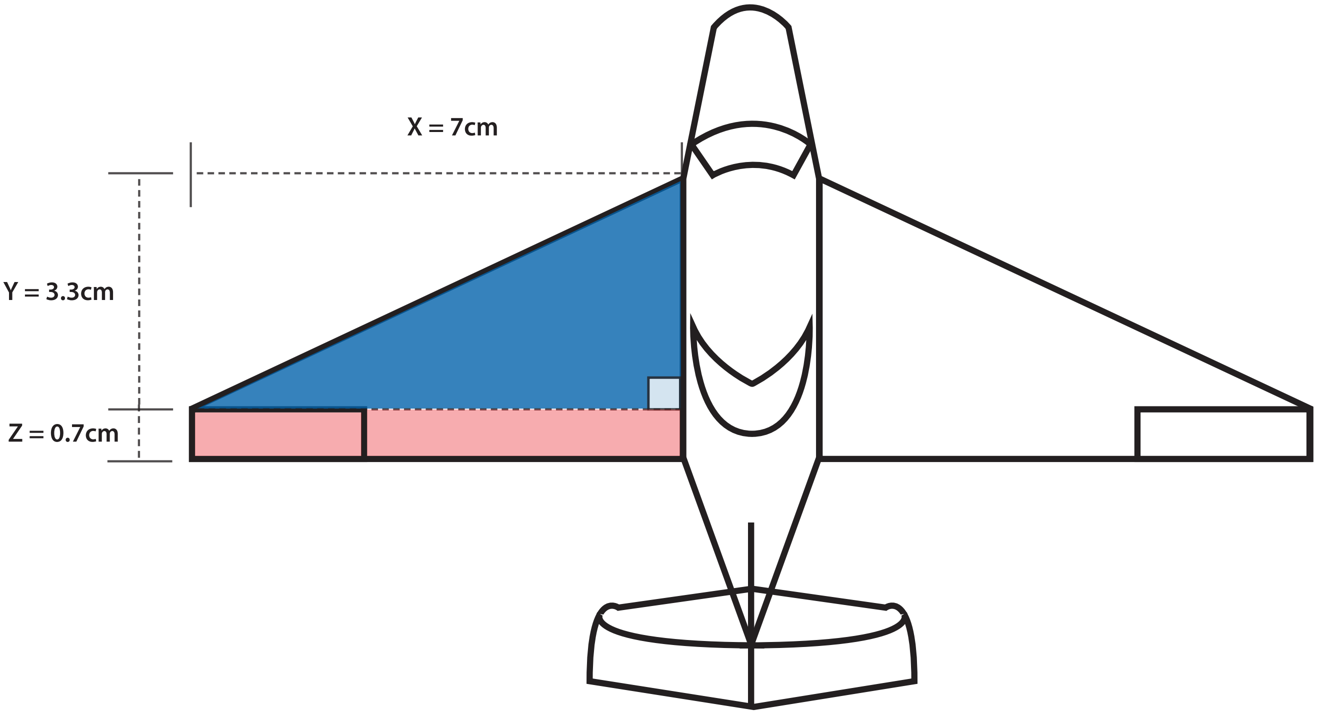
Divide the mean chord by the length.

$$\text{Aspect Ratio} = \frac{2.05\text{cm}}{8\text{cm}} = 0.26$$

$$\text{Aspect Ratio} = \frac{\text{Mean Chord}}{\text{Length}}$$

Surface Area of a Rectangle = Length x Height

$$\text{Surface Area of a Right Triangle} = \frac{1}{2}(\text{Length x Height})$$



Plane #3

a. Calculate the surface area of one wing.

Seperate the wing into a right triangle and a rectangle. Calculate the area of each shape, then add them together.

$$\text{Surface Area} = (7\text{cm} \cdot 0.7\text{cm}) + \frac{1}{2}(7\text{cm} \cdot 3.3\text{cm}) = 4.9\text{cm} + 11.55\text{cm} = 16.45\text{cm}$$

b. Calculate the length of the mean chord.

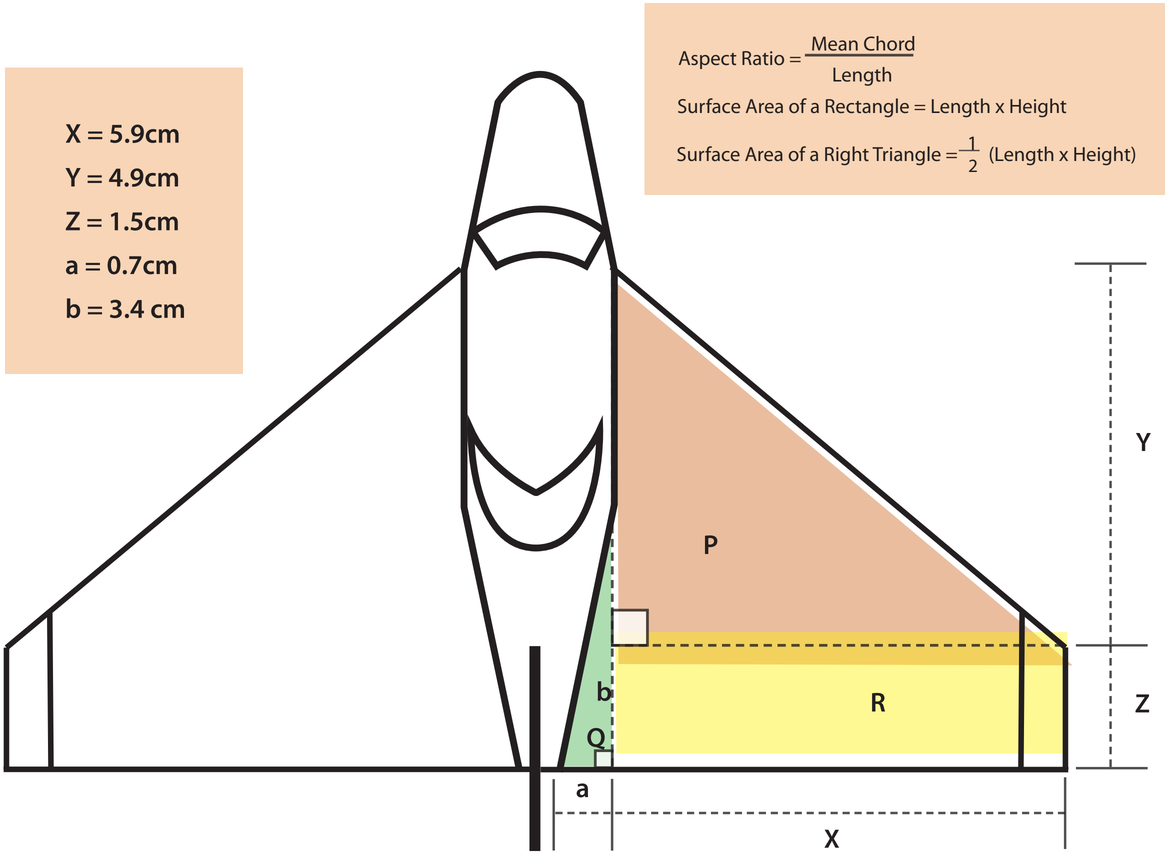
Find the average between the length of the wing's root (y+z) and the length of the wing's tip (z).

$$\text{Mean Chord} = \frac{(3.3\text{cm} + 0.7\text{cm}) + 0.7\text{cm}}{2} = 2.35\text{cm}$$

c. Calculate the wing's aspect ratio.

Divide the mean chord by the length.

$$\text{Aspect Ratio} = \frac{2.5\text{cm}}{7\text{cm}} = 0.34$$



X = 5.9cm

Y = 4.9cm

Z = 1.5cm

a = 0.7cm

b = 3.4 cm

$\text{Aspect Ratio} = \dfrac{\text{Mean Chord}}{\text{Length}}$

Surface Area of a Rectangle = Length x Height

$\text{Surface Area of a Right Triangle} = \dfrac{1}{2}\,(\text{Length x Height})$

Plane #4

a. Calculate the surface area of one wing.

(Surface Area of Triangle P) + (Surface Area of Triangle Q) + (Surface Area of Rectangle R)

$$\text{Surface Area} = \left(\tfrac{1}{2}(5.9\text{cm} \cdot 4.9\text{cm})\right) + \left(\tfrac{1}{2}(0.7\text{cm} \cdot 3.4\text{cm})\right) + (5.9\text{cm} \cdot 1.5\text{cm}) = 24.45\text{cm}$$

b. Calculate the wing's aspect ratio.

When the mean chord's length is unknown, divide the wing's surface area by the square of the wingspan (the longest part of the wing's length; in this case, a + x).

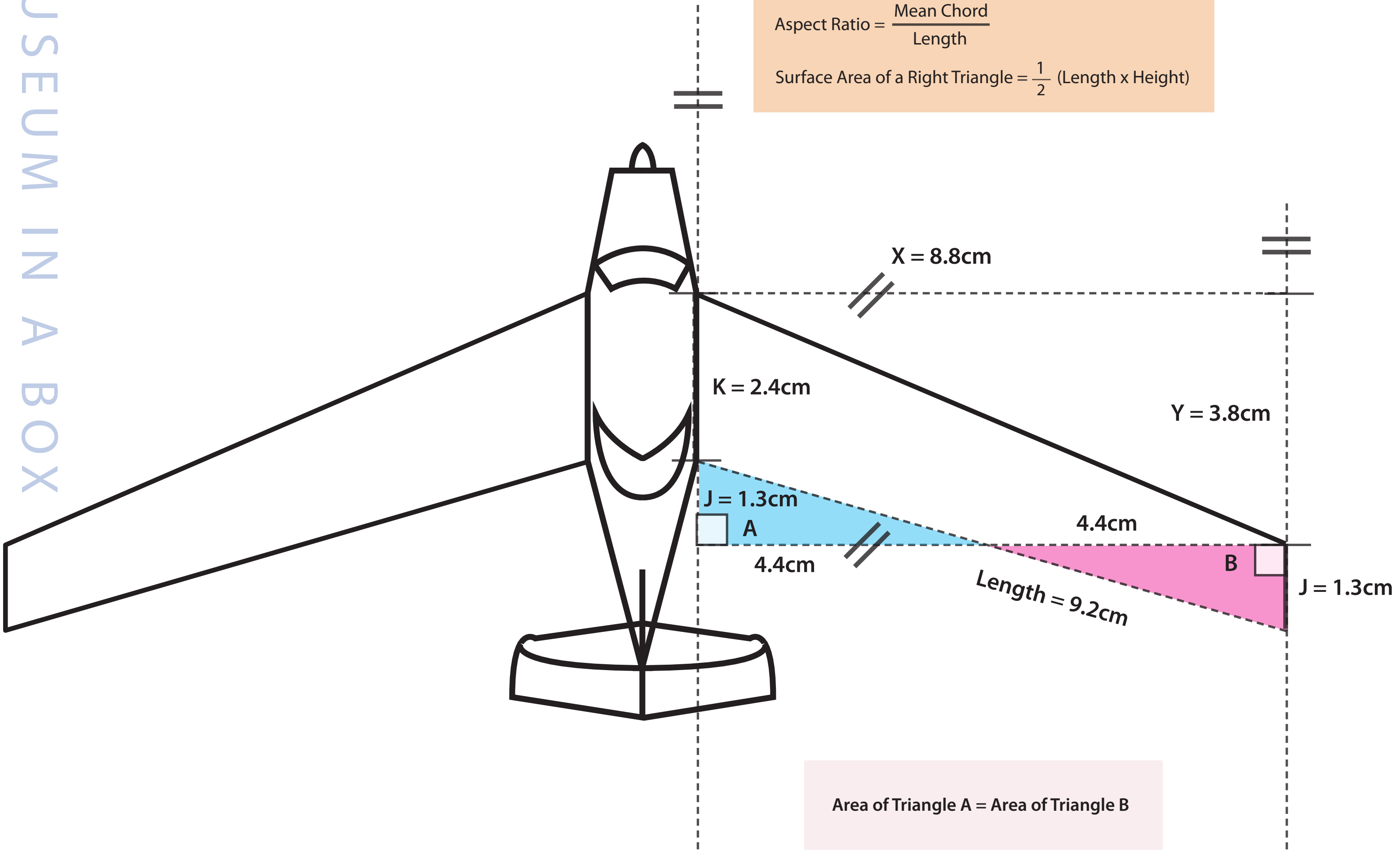
$$\text{Aspect Ratio} = \frac{\text{Surface Area}}{\text{Length}^2} = \frac{24.45\text{cm}}{(0.7\text{cm} + 5.9\text{cm})^2} = 0.56$$

c. Determine the length of the mean chord.

Use the formula $\text{Aspect Ratio} = \dfrac{\text{Mean Chord}}{\text{Length}}$ *to calculate the length of the mean chord.*

Multiply the length of the longest part of the wing by the aspect ratio.

$$\text{Mean Chord} = \text{Length} \cdot \text{Aspect Ratio} = (0.7\text{cm} + 5.9\text{cm}) \cdot 0.56 = 3.7\text{cm}$$



$$\text{Aspect Ratio} = \frac{\text{Mean Chord}}{\text{Length}}$$

$$\text{Surface Area of a Right Triangle} = \frac{1}{2}\,(\text{Length x Height})$$

Area of Triangle A = Area of Triangle B

Plane #5

a. **Calculate the surface area of one wing.**

Because Triangle A = Triangle B, the surface area of this wing is the area of the triangle with base X and height Y. Multiply the length by the height, then divide by 2.

$$\text{Surface Area} = \frac{1}{2}(8.8\text{cm} \bullet 3.8\text{cm}) = 16.72\text{cm}$$

b. **Calculate the length of the mean chord.**

The mean chord is equal to one half of the height of the wing.

$$\text{Mean Chord} = \frac{2.4\text{cm} + 1.3\text{cm}}{2} = 1.85\text{cm}$$

c. **Calculate the wing's aspect ratio.**

Divide the mean chord by the length.

$$\text{Aspect Ratio} = \frac{1.85\text{cm}}{9.2\text{cm}} = 0.2$$

Discussion Points:

1. **What benefit does calculating the aspect ratio provide when designing a wing?**
   The aspect ratio directly relates to the ability of the wing to provide lift. Wings with higher aspect ratios will produce a lot of lift at fairly slow speeds but in turn produce a lot of drag, which equates to a slower overall aircraft.

2. **If you had to design a rectangular wing with an aspect ratio of 8.5, but were limited to a total wingspan of 40 meters, what distance would the chord line be?**

   $$\frac{40m}{8.5} = 4.71m$$

3. **After building the wing from #2 above, you discovered the aircraft couldn't fly fast enough to produce sufficient lift to fly. What could be done to improve the wing's lift-producing qualities?**
   By increasing the camber, or curvature of the upper surface of the wing, you can increase the amount of lift a wing can produce. This also causes additional drag however, so the maximum speed of the aircraft (in flight) is reduced proportionately.

NATIONAL SCIENCE STANDARDS K-4

SCIENCE AS INQUIRY

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PHYSICAL SCIENCE

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NATIONAL SCIENCE STANDARDS 9-12

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- Understanding about science and technology

NATIONAL MATH STANDARDS K-12

NUMBER AND OPERATIONS

- 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

- Represent and analyze mathematical situations and structures using algebraic symbols
- Use mathematical models to represent and understand quantitative relationships

MEASUREMENT

- 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

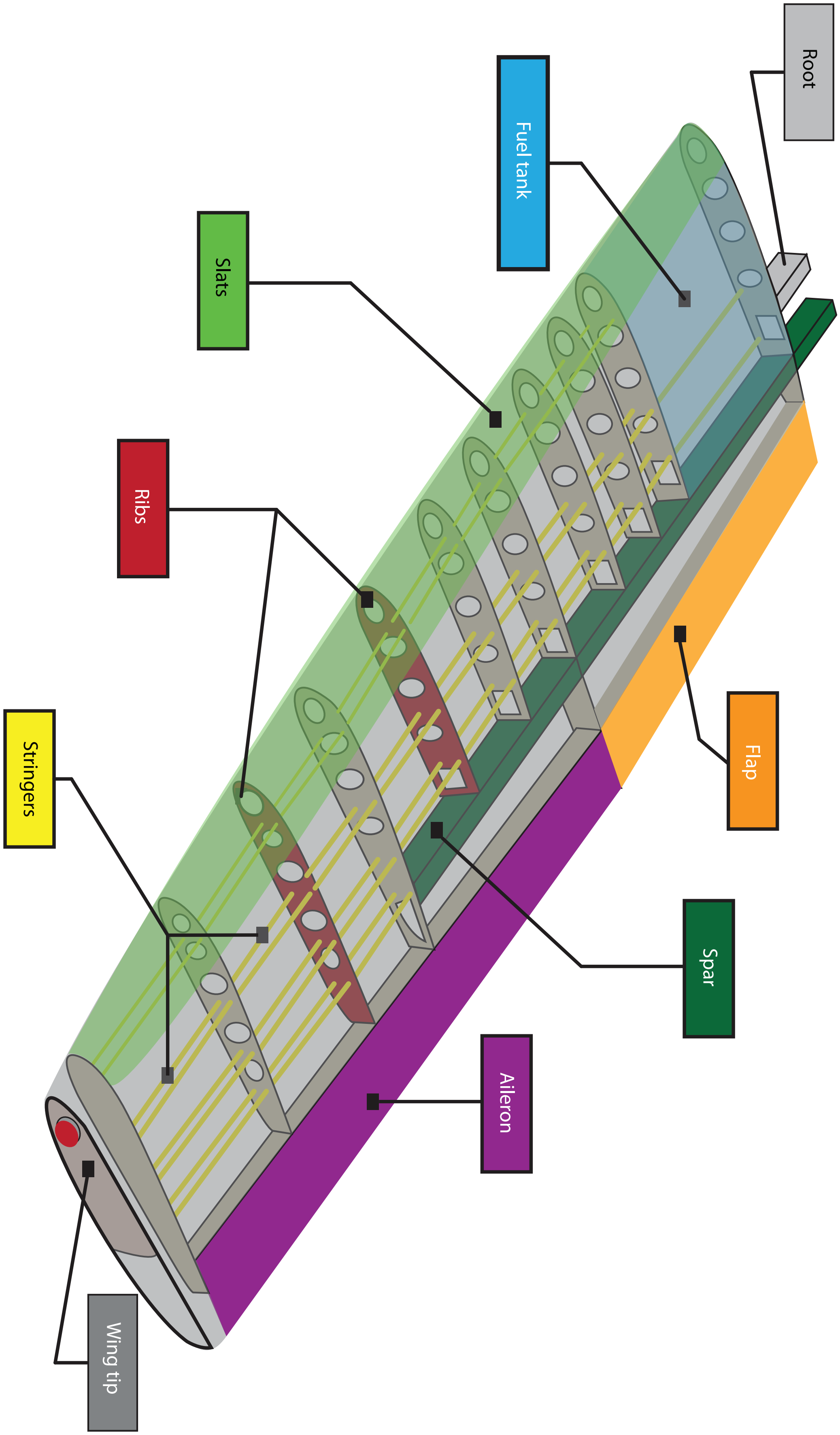
- Formulate questions that can be addressed with data and collect, organize, and display relevant data to answer them

PROCESS

- Problem Solving
- Communication
- Connections
- Representation

Reference Materials

Fig. 1 The components of a wing



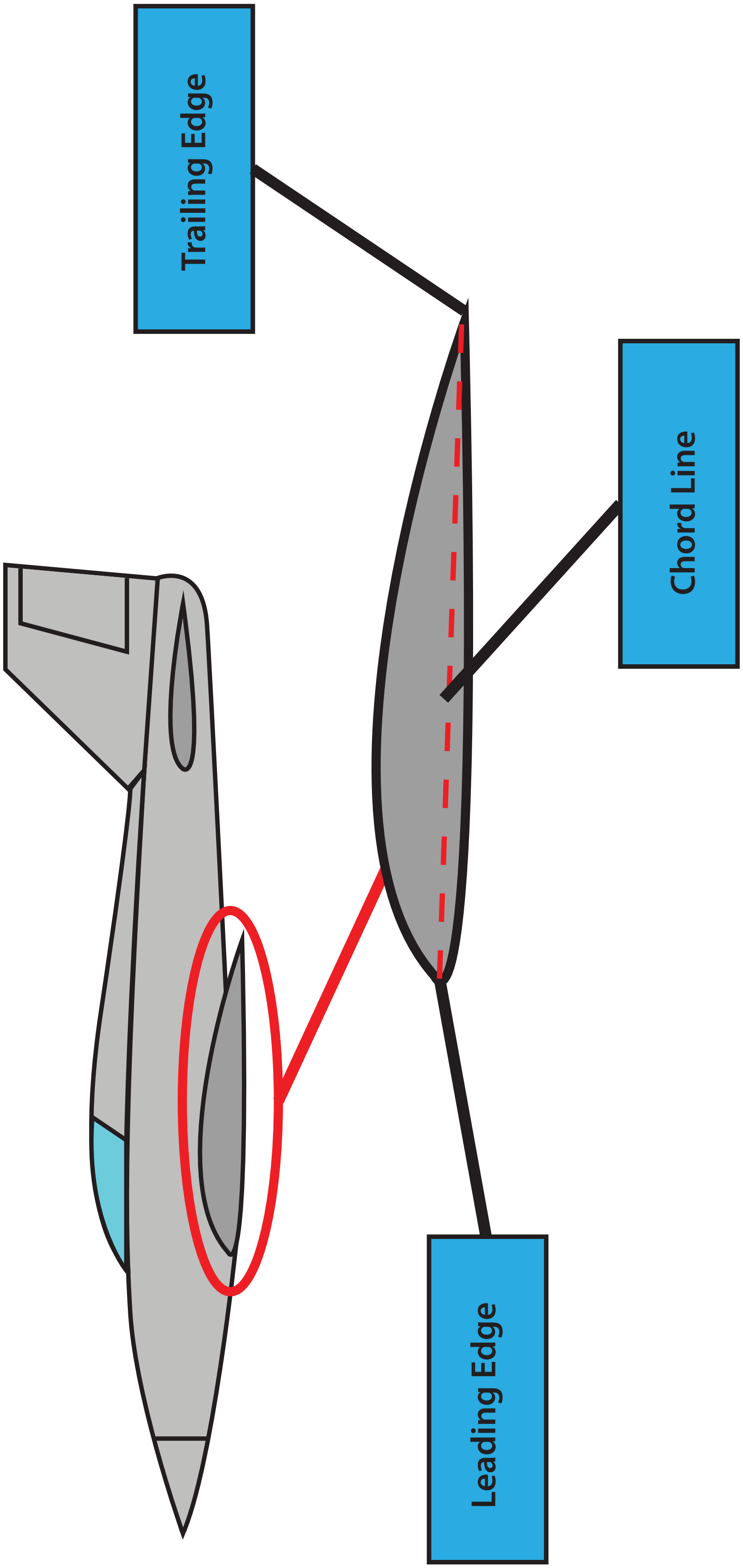


Fig. 2 Wing cross-section

Fig. 3 Lockheed Martin F-22 "Raptor" Planform Silhouette

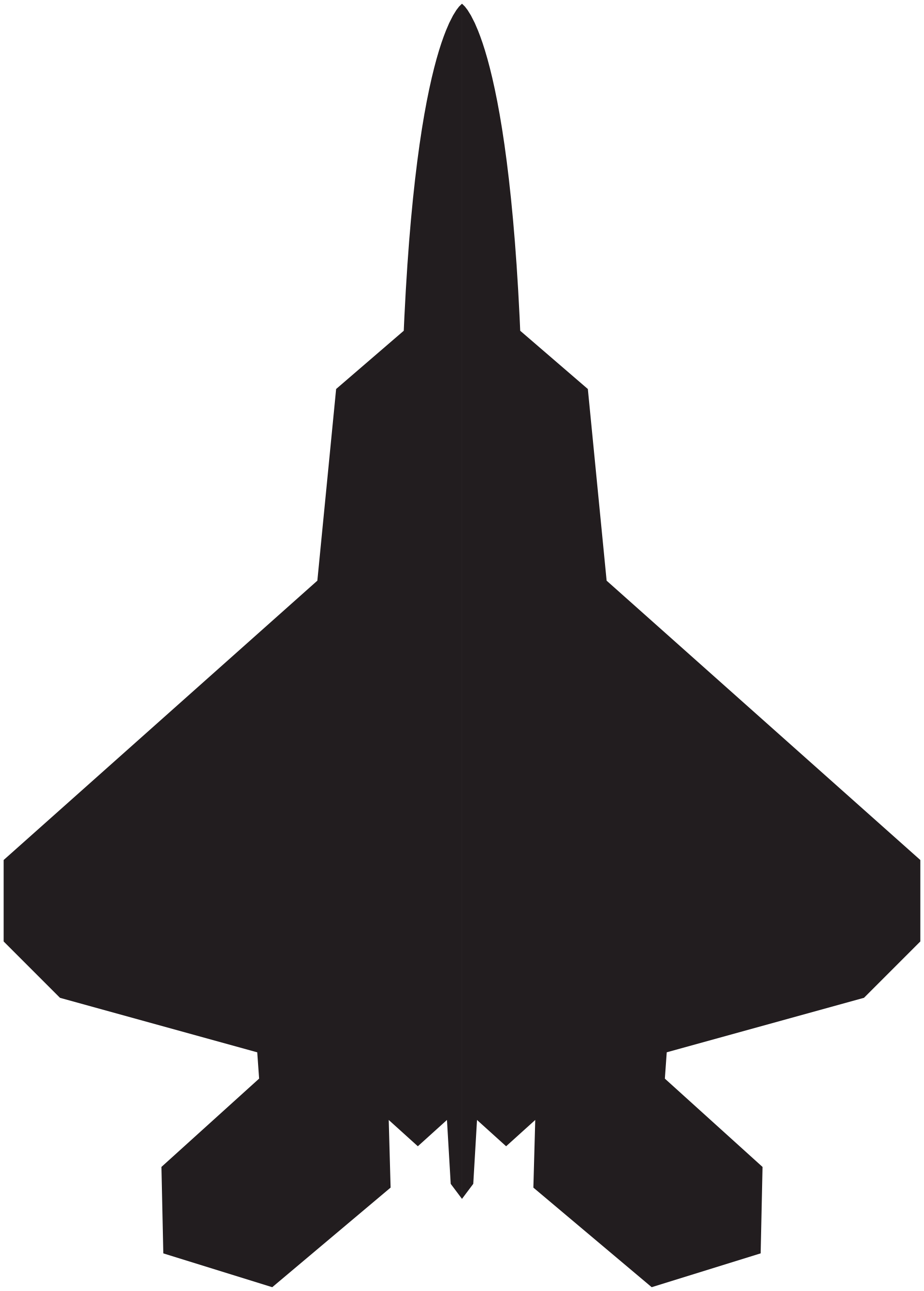


Fig. 4 Cessna T-37 “Tweet” Planform Silhouette

Fig. 5 McDonald Douglas KC-10 “Extender” Planform Silhouette

Fig. 6 Lockheed Martin/NASA ER-2 Planform Silhouette

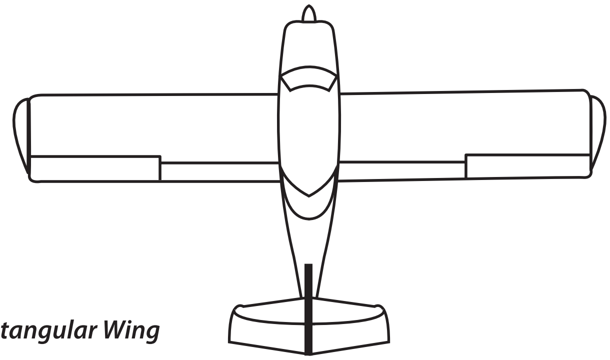
Student Worksheets

Worksheet 1 Avian Feather Comparison

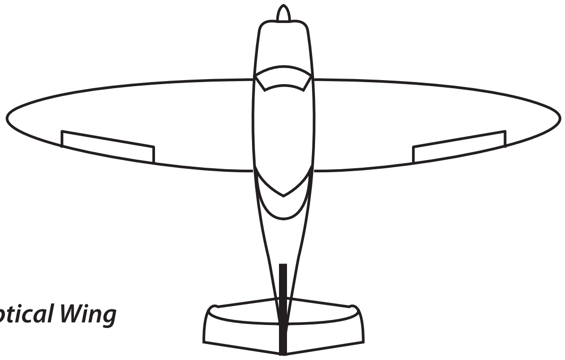
Turkey Feather	Ostrich Feather

Worksheet 2

Wing Designs



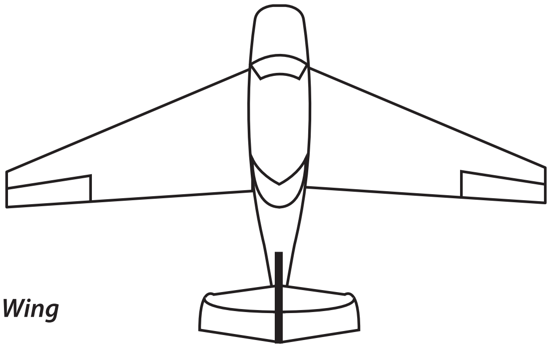
Rectangular Wing



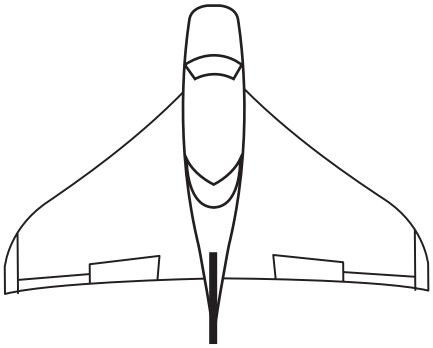
Elliptical Wing

Notes:

Notes:



Swept Wing



Delta Wing

Notes:

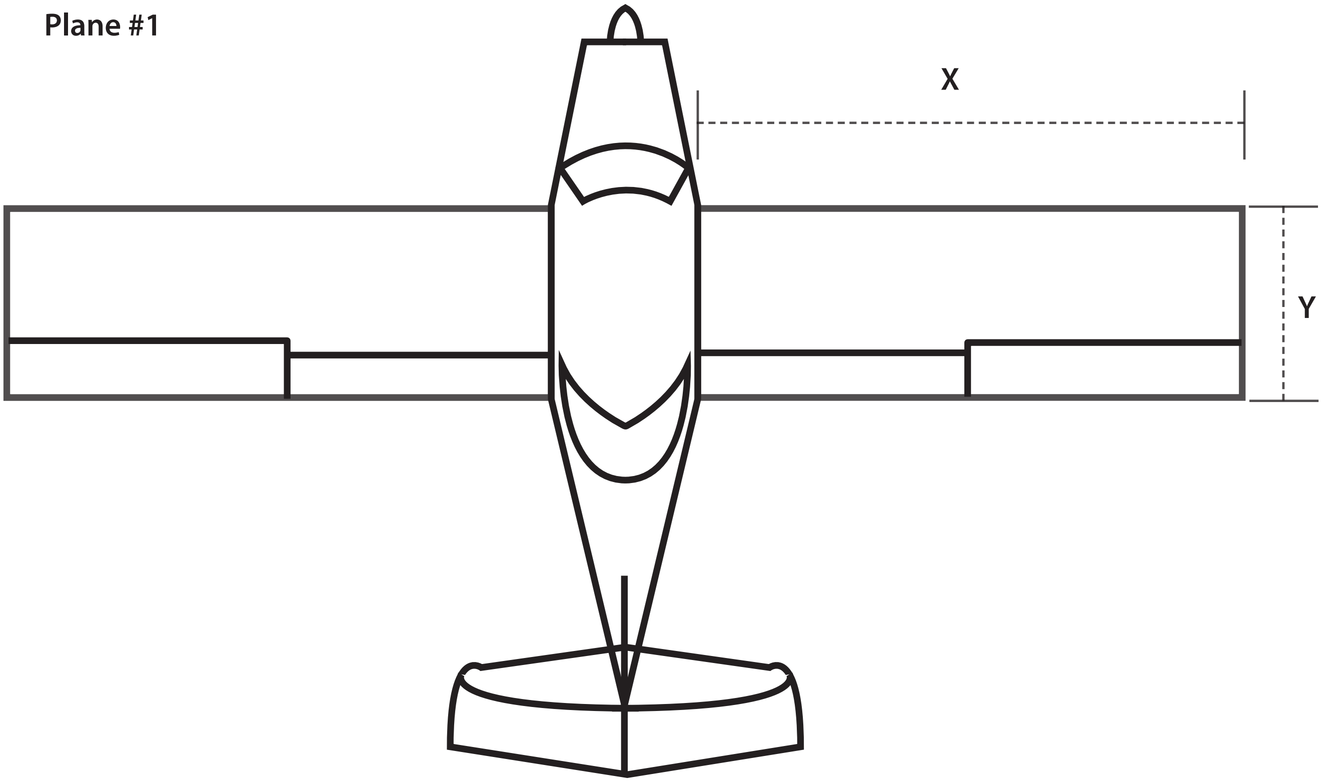
Notes:

Worksheet 3 Wing Math

Surface Area of a Rectangle = Length x Height

$$\text{Aspect Ratio} = \frac{\text{Mean Chord}}{\text{Length}} = \frac{Y}{X}$$

Plane #1



Surface Area =

Mean Chord =

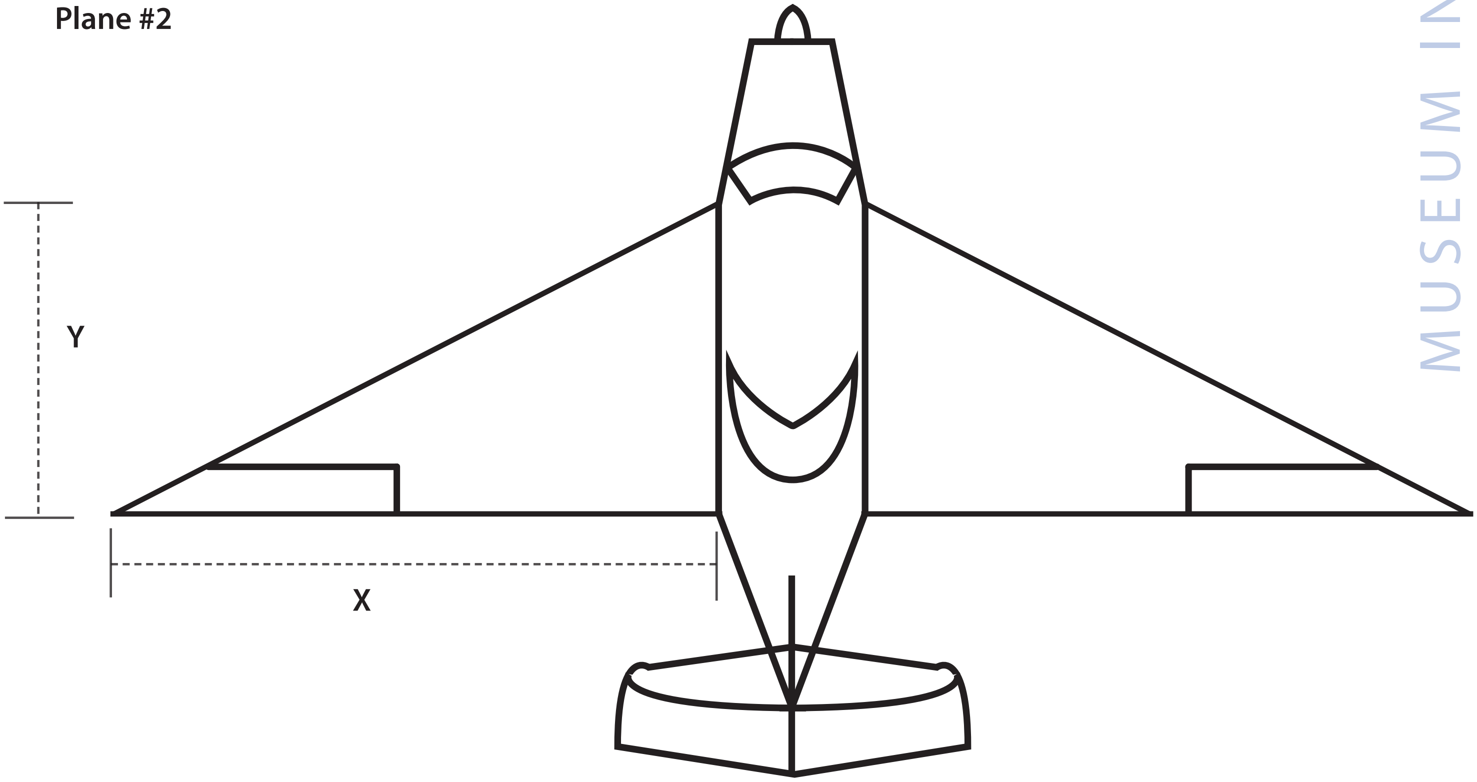
Aspect Ratio =

Worksheet 3 (cont.) Wing Math

Surface Area of a Right Triangle = $\frac{1}{2}$ (Length x Height)

Aspect Ratio = $\frac{\text{Mean Chord}}{\text{Length}} = \frac{Y}{X}$

Plane #2



Surface Area =

Mean Chord =

Aspect Ratio =

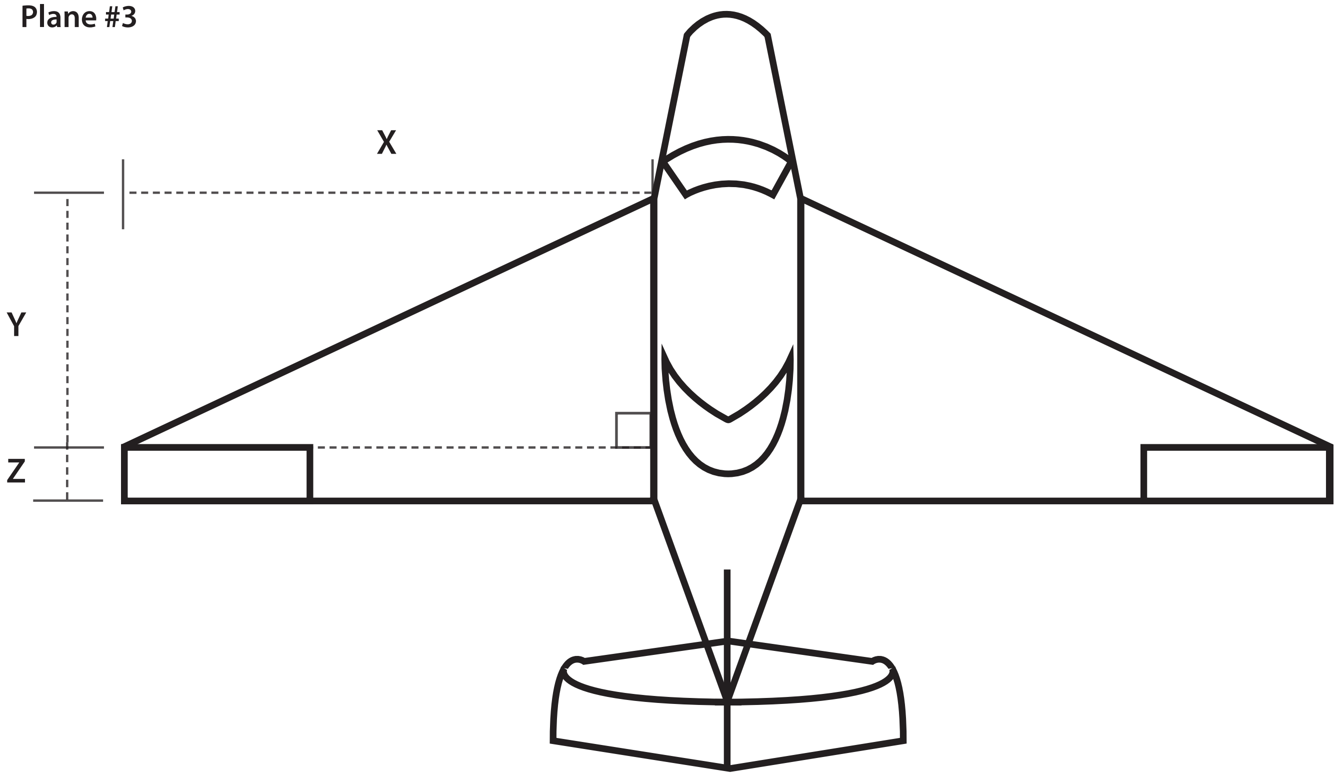
Worksheet 3 (cont.) Wing Math

Surface Area of a Rectangle = Length x Height

Surface Area of a Right Triangle = $\frac{1}{2}$ (Length x Height)

Aspect Ratio = $\frac{\text{Mean Chord}}{\text{Length}} = \frac{\frac{(Y + Z) + Z}{2}}{X}$

Plane #3



Surface Area =

Mean Chord =

Aspect Ratio =

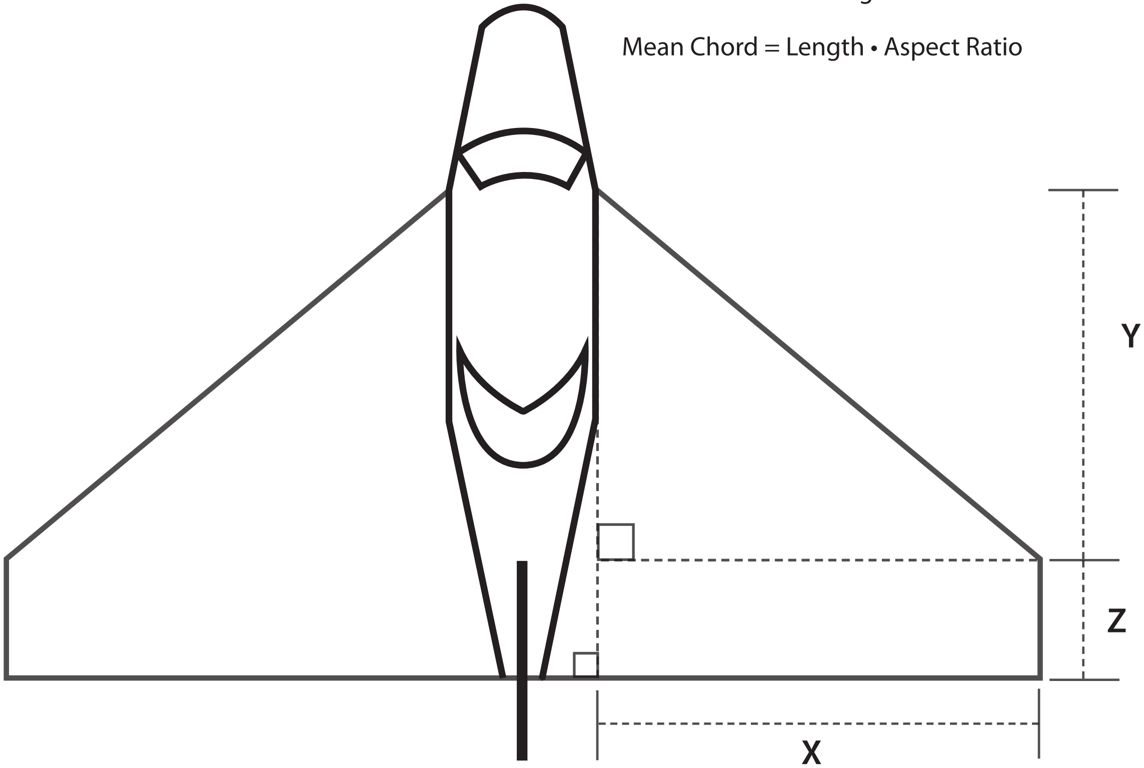
Surface Area of a Rectangle = Length x Height

Surface Area of a Right Triangle = $\frac{1}{2}$ (Length x Height)

Aspect Ratio = $\frac{\text{Surface Area}}{\text{Length}^2}$

Mean Chord = Length • Aspect Ratio

Plane #4



Surface Area =

Aspect Ratio =

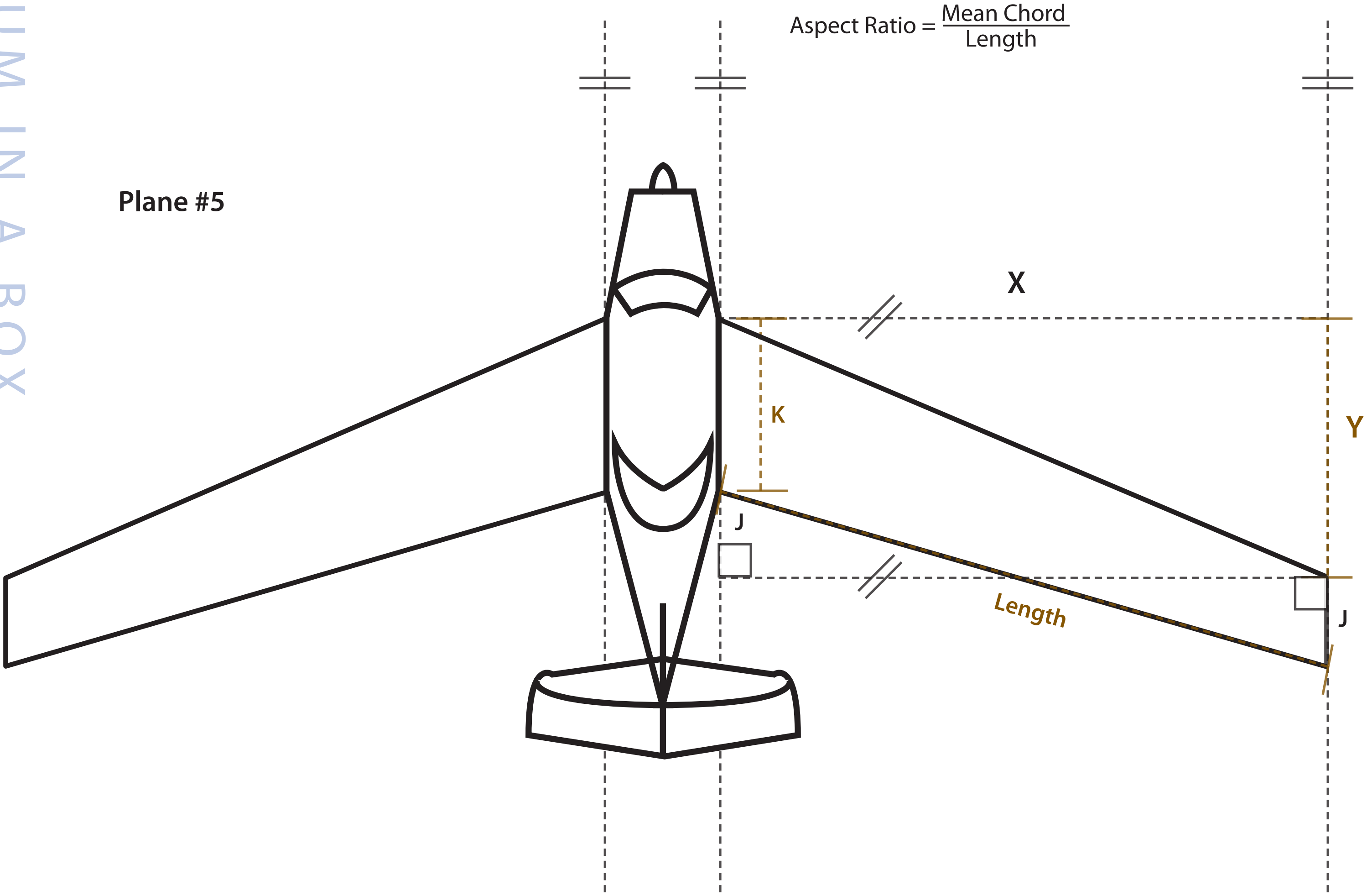
Mean Chord =

Worksheet 3 (cont.) Wing Math

Surface Area of a Right Triangle = $\frac{1}{2}$ (Length x Height)

Aspect Ratio = $\frac{\text{Mean Chord}}{\text{Length}}$

Plane #5



Surface Area =

Mean Chord =

Aspect Ratio =

Images

Img. 1 The 1903 Wright Flyer

(Photo courtesy of Wikipedia, GNU Free Documentation License)

Img. 2 Boeing 787

(Photo courtesy of Boeing)

Img. 3 An ostrich with folded wings

(Photo courtesy of Lost Tribe Media, Inc.)

Img. 4 A seagull in flight

(Photo courtesy of Arnold Paul, CC BY-SA 2.5 License)

Img. 5 A robin in flight

(Photo courtesy of Arnold Paul, CC BY-SA 2.5 License)

Img. 6 A Russian TU-144 Supersonic Passenger Jet

(Photo courtesy of NASA)

Img. 7 The BOAC Concorde Supersonic Passenger Jet

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Img. 8 Turkey

(Photo courtesy of the United States Department of Agriculture)

Img. 9 Ostrich

(Photo courtesy of Kwolana & Wikipedia – GNU Free Documentation License)

Img. 10 Lockheed Martin F-22 “Raptor”

(Photo courtesy of the United States Air Force)

Img. 11 Cessna T-37 "Tweet"

(Photo courtesy of the United States Air Force)

Img. 12 McDonald Douglas KC-10 “Extender”

(Photo courtesy of the United States Air Force)

Img. 13 Lockheed Martin/NASA ER-2

(Photo courtesy of the NASA)

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