Title: The Control Line Plane, Quadratic Regression and Flight Theory

Brief Overview:

The major focus of this lesson is to instruct students about the theory of flight and then to design, and construct an electrically powered control line plane. The quadratic regression will be discussed in the follow up lesson. The cost of the supplies needed to construct each plane is approximately $2. The students can be organized into groups of 2 to 3 students to construct the motorized plane. The teacher will also need to spend $200 on a power supply and a center power pole. The mathematical connection is the quadratic regression that the student can perform on the data that is obtained from the plane launch and the calculation of the wings' Aspect Ratio.

NCTM 2000 Principles for School Mathematics:

- **Equity:** *Excellence in mathematics education requires equity - high expectations and strong support for all students.*

- **Curriculum:** *A curriculum is more than a collection of activities: it must be coherent, focused on important mathematics, and well articulated across the grades.*

- **Teaching:** *Effective mathematics teaching requires understanding what students know and need to learn and then challenging and supporting them to learn it well.*

- **Learning:** *Students must learn mathematics with understanding, actively building new knowledge from experience and prior knowledge.*

- **Assessment:** *Assessment should support the learning of important mathematics and furnish useful information to both teachers and students.*

- **Technology:** *Technology is essential in teaching and learning mathematics; it influences the mathematics that is taught and enhances students' learning.*

Links to NCTM 2000 Standards:

- **Content Standards**

  <u>Number and Operations</u>
  Students will use formulas to calculate Average Chord, Wing Area and Aspect Ratio. The students will also calculate the speed of their plane at multiple points.

  <u>Algebra</u>
  Students will use collected data to perform a quadratic regression.

Geometry
Students will use their knowledge of geometric shape in the development of their wings. The students will use the formula, Circumference = (Pi) x Diameter.

Measurement
Students will measure, design and construct a wing from scratch. The students will also cut out a template, trace on Styrofoam, cut out and glue together the plane's body.

Data Analysis and Probability
Students will create a graph showing the relationship between Aspect Ratio and take off time. The students will record data detailing flight times and distance.

- **Process Standards**

Problem Solving
Students will analyze their data, and use their problem solving skills to hypothesize and draw conclusions about optimal Aspect Ratio and curvature needed to get maximum lift for an expedient take off.

Communication
Students will write a report that should link their hypotheses to their data, lessons, constructions and theories of the dynamics of flight.

Links to Maryland High School Mathematics Core Learning Units:

Functions and Algebra
- Develop an understanding of properties of, and representations for, the addition and multiplication of vectors and matrices.
- Develop fluency in operations with real numbers, vectors, and matrices, using mental computation or paper-and-pencil calculations for simple cases and technology for more-complicated cases.
- Judge the reasonableness of numerical computations and their results.
- Analyze functions of one variable by investigating rates of change, intercepts, zeros, asymptotes, and local and global behavior.
- Use symbolic algebra to represent and explain mathematical relationships.
- Approximate and interpret rates of change from graphical and numerical data.

Geometry, Measurement, and Reasoning
- Draw and construct representations of two- and three-dimensional geometric objects using a variety of tools.
- Use geometric ideas to solve problems in, and gain insights into, other disciplines and other areas of interest such as art and architecture.
- Make decisions about units and scales that are appropriate for problem situations involving measurement.
- Understand and use formulas for the area, surface area, and volume of geometric figures, including cones, spheres, and cylinders.

Links to National Science Education Standards:

- **Science as Inquiry**
  Students will first develop hypotheses concerning the Surface Ratio of the wing and its connection to take-off time and lift. They will then use the scientific method to test these hypotheses and write a formal report.

- **Physical Science**
  Students will apply the concepts of the forces of flight, vector forces, air resistance, and yaw, pitch and roll to both design their wings and adjust their planes after each trial flight.

- **Science and Technology**
  Students will be designing the wings for their airplanes using their background knowledge and building according to these designs.

Links to Maryland High School Science Core Learning Units:

- **Concepts of Physics**
  Students will be using many aeronautical concepts in designing the wings for their planes. In order to make the plane electrically powered, they will also be introduced to some basic electrical engineering concepts.

Grade/Level:

Grades 8-12

Duration/Length:

Approximately four hours, depending on quantity of materials available

Prerequisite Knowledge:

Students should have working knowledge of the following skills:

- Basic geometry equations involving the circle
- The Scientific Method
- Basic comprehension of air pressure
- Understanding of the rules of safety when working around construction tools

Student Outcomes:

Students will:

- build a prototype of a wing.
- modify their wing to create maximum lift and optimal aspect ratio.
- work with the stated mathematical formulae to calculate aspect ratio.
- build an entire motorized control line airplane.
- analyze their data, and use their problem solving skills to hypothesize and draw conclusions.

Materials/Resources/Printed Materials:

(One of each needed per group)

- Stop watch
- Styrofoam Template (Included)
- 2 Sheets of Styrofoam
- 1 Hi-Speed Motor (available through Kelvin Electronics for 65 cent - Item # 850647)
- 1 - 6 inch Landing Gear Wire (available through Kelvin for 7 cent per piece- Item # 850932)
- 2 - 5/8 inch diameter Wood Landing Wheels (available for 20 cent per set- Item # 850934)
- 1 - 3 inch Hi-Speed Propeller (available for $1.20 cent per propeller - Item # 850590)
- 1 - 8 foot phone cord with one end cut (available at any electronics store)
- 1 - 12-16 volt Power Supply with Polarity Switch ($99.95 cent per unit - Item # 850627)
- 1 - Power pole ($99.95 cent per unit - Item # 850747)
- 1 - Low Temperature Hot Glue Gun (available at any hardware store for approximately $10)
- 1 - Hot Glue Stick (available at any hardware store for approximately $5 for 30)
- 1 - Soldering Iron and 1 spool of .032 diameter 6/40 Rosen Core Solder

Development/Procedures:

- Complete the “Introduction to Flight Dynamics” activity. You may choose to make each section a complete lesson with more detail.
- Using the section “Geometry of a Wing”, review the characteristics of an ideal wing for the control line plane.
- Hand out the template and the “Can You Wing It” activity.
- Allow students to design their wings and then complete the activity.
- Before students test their wings, choose a few distinct types of wings and have students make hypotheses regarding the amount of lift and take-off time for those wings.
- Test them out! Give each wing 3 trials, using the best take-off time for each. Minor adjustments should be allowed between trials.

Assessment:

You may choose to give a score to the students based on their take-off time. This would be reasonable in a Physics or other high-level course. If you are doing this activity as an introduction to flight dynamics, an enrichment activity, or for a lower grade level, the true assessment should be the lab report. In this report, the students can trace their steps through the Scientific Method and discuss their conclusions based on the take-off times of different wings. A possible scoring rubric for these reports is attached.

Extension/Follow Up:

For a higher level course, you can introduce the Trigonometry concepts of flight, using vector analysis to compensate for and analyze such factors as wind direction and speed, fuel consumption rate, and route of flight

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Introduction to Flight Dynamics

Background

The theory of aerodynamics is the culmination of the works of many different individuals. It began with prehistoric man's desire to copy the actions of the bird and fly through the air. Being unable to soar into the heavens, early man attributed to his gods the ability to soar. Greek philosophers, such as Aristotle and Archimedes, and other men like Galileo, Roger Bacon, and Pascal investigated the substance called air. Leonardo da Vinci, through his intensive studies of bird flight, came up with the principles and designs that influenced many. The first flying machine to carry man did not imitate the birds. Instead it was based on the lighter-than-air principle and took the form of a large hot air balloon. Constructed in 1783 by the two Montgolfier brothers from France the balloon holds the distinction of being the first ascent of man into the atmosphere. Heavier-than-air flight did not get "off the ground" until the late 1800's. The most recognized men in the early years of airplane flight are the brothers, Orville and Wilbur Wright. The first powered flight of a manned aircraft, the Wright Flyer, took place on December 17, 1903, and ushered in the "Air Age."

There are four forces that act upon an aircraft in flight: gravity, lift, drag, and thrust. Gravity is the natural force which the Earth produces as a result of its mass. Gravity will keep an airplane on the ground or pull it back to Earth unless there is an equal or greater force to overcome the effect of gravity (Newton's Law of Motion). This opposing force is called lift. Lift is created in a fixed-wing aircraft by changes in air pressure around an airplane's wing as the airplane moves along the ground of through the air (Bernoulli's Principle).

In the beginning, attempts by humans to fly with wings were unsuccessful because they failed to understand two important factors when observing bird's wings. A bird's wing is not attached to the bird level with its body, or direction of flight. The front of the wing, or leading edge, is higher than the back, or trailing edge. On an airplane, this is called angle of attack.

Bernoulli’s Principle Demonstration

1. Cut out a long, thin strip of paper.
2. Put the paper in a book by inserting about 1 inch of it between the center pages of the book.
3. Hold the book upright in front of your mouth so that the paper hangs over the far side of the book.
4. Blow gently across the top of the paper. Record what happens:

All fluids exert pressure. Air flows in fluid motion. Gases, like air exert pressure. The motion of' the particles of' the gases and the downward pull of' gravity produce this pressure. The fact that gases exert pressure is the mysterious secret of flight.

If you did the experiment correctly, the piece of paper is pushed upward, or lifted. You have demonstrated Bernoulli's principle, which describes the pressure in a stream of air. When you blow across the top of the paper, you produce a stream of air. The pressure in this stream is less than the pressure in the surrounding air. So the air pressure under the paper is greater than the air pressure above it. The paper is pushed tip into the moving air.

Wing Design

Think about the shape of the wing on an airplane. The wing is round in the front, thick in the middle, and narrow at the back. The bulge in the upper surface makes this surface longer than the lower surface. So when the wing moves forward, the air above the wing must travel a longer distance than the air below the wing. In order to travel this longer distance, the air above the wing must move faster. Where the air is flowing faster, there is less pressure. So the pressure on the top of the wing is less than the pressure on the bottom. And the wing is pushed upward!

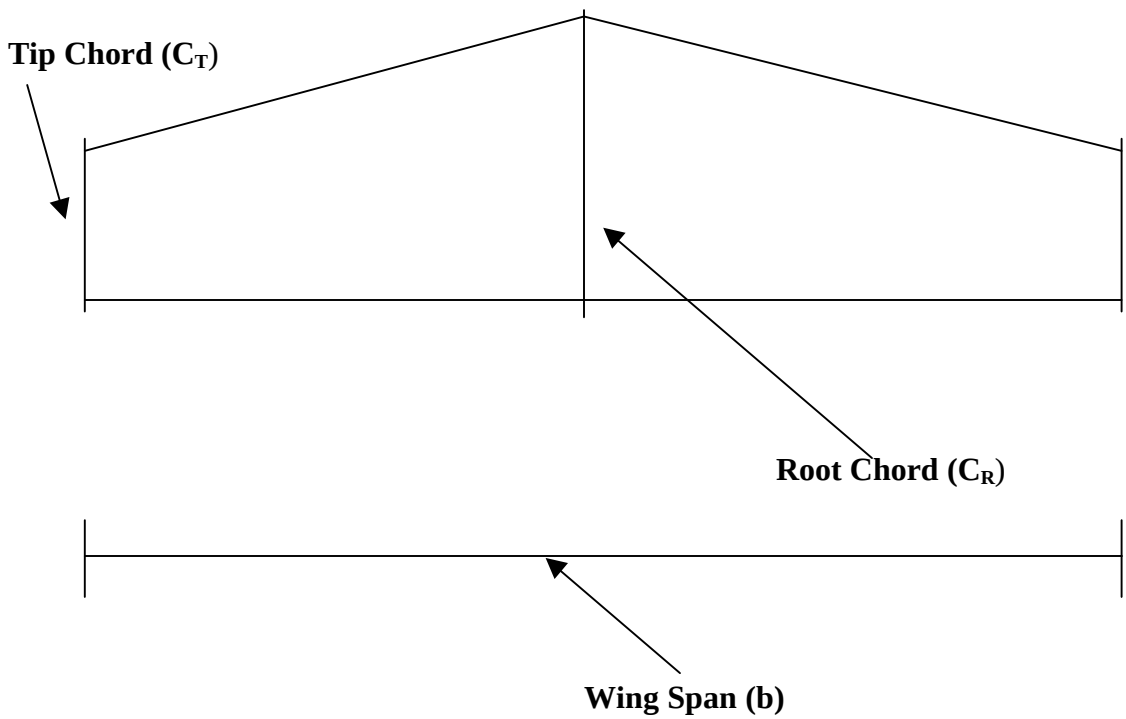
The upward force on the wings is called **lift**. It is lift that keeps objects in flight, like birds, bees, and jumbo jet planes. When the airplane is in level flight, the lift is equal to the weight of the airplane. It may be obvious to you now that the less the weight of the airplane, the less lift is needed for flight. This idea is very important when building your plane. The motors we will use provide very low thrust relative to the planes weight .

As an airplane moves through the air, it exerts a forward force called **thrust.** But the air also exerts a force. Which slows the plane's motion. Think of what happens when you stick your hand out of the window of your moving car. This backward force is called **drag**. Since drag resists motion, it tends to slow an airplane down. Drag can be reduced by making air pass more smoothly along the airplane's surfaces. So airplanes are designed with pointed fronts and thin tails. This streamlined design produces less drag.

What has all this to do with the airplane that you are going to build? You and your classmates are going to build an airplane. The body of each student’s plane will be relatively identical. The one difference in each student’s plane will be the wing. Each student will design and build their own wing. Lift is also caused by the resultant force of gravity and thrust on the object in motion. Since each student will be given the same motor and use the same power supply, this lift component will be similar for each student

Geometry of a Wing

The efficiency of an airplane’s wing is largely dependent on the shape and size of the wing. The wing area is the wing span (**b**) multiplied by the Average Chord (**c)** where the average chord is equal to the tip chord plus the root chord divided by two. The Aspect Ratio is the Wing Span divided by the Average chord. Use the sketch on the next page as a birds eye perspective that should assist with identification of a wings characteristics.



$\mathbf{C_R}$ = Root Chord
$\mathbf{C_T}$ = Tip Chord
b = Wing Span
$\overline{C}$ = Average Chord = $\frac{\mathbf{C_R} \times \mathbf{C_T}}{2}$

$\mathbf{S_{ref}}$ = Wing Area = $\mathbf{b} \times \overline{\mathbf{C}}$

$\mathbf{AR}$ = Aspect Ratio = $\frac{\mathbf{b}}{\overline{\mathbf{C}}} = \frac{\mathbf{b^2}}{\mathbf{S_{ref}}}$

The aspect ratio of a wing is very important when designing a wing. A low aspect ratio wing can be put on a plane with a lot of thrust, and can withstand a high speed. A high aspect ratio wing can be put on a plane with little thrust, and cannot withstand a high speed. A high-speed military fighter jet would have wings with a low aspect ratio since it would travel at high speeds and require precision maneuverability. A glider's wing would have a high aspect ratio since it would travel at very low speeds.

Name_____

Can You Wing It?

Objective

You will design and build a wing that will get your plane off the ground. You want your plane to take off before any other group's plane does. A timer will start the moment you and your partner apply voltage to the motor on your plane. It will stop the moment the wheels leave the ground. Your plane is required to stay aloft for a specific time period. You can only "power up" your plane's motor to a set limit. The plane that has the quickest "take off" time will win. The speed will also be calculated at each rotation.

Step One - Your Wing

You and your partner(s) will design a wing to get your plane up quickly and keep it in the air for at least 5 seconds. Every group will use the same Styrofoam Template, thus each group will have a limited wing span (b), root chord (CR), and tip chord (CT).

Step Two - Cutting the Wing

You and your partner(s) should carefully cut out the wing you designed on the paper. Trace the design of the wing onto one of the pieces of Styrofoam. Carefully cut your wing from the Styrofoam.

Step Three - Building the Control Line Plane

1. Carefully cut out each piece of the plane from the paper template.

2. Trace each piece you cut out from the template onto your second piece of Styrofoam.

3. Glue the two body sections of your plane together to promote strength. Do not use too much glue, as this will create more weight.

4. Use a ruler to crease the dotted line along the rear wing elevators. Glue the rear wing and rear fin onto the body of the plane. This crease will allow adjustments, to gain quickest flight.

5. While maintaining a right angle with the plane's body, carefully glue on the wing and motor mounts.

6. Glue on your wing. Try to keep the wing at a right angle to the planes body.

7. Use the soldering iron to prepare motor for installation. Glue the motor on to its mount.

8. Use pliers to bend landing gear into shape.
9. Put on wheels, and glue on landing gear. Wheels should spin freely.

10. Push propeller onto motor. Propeller should not hit the wing..

11. Use paper clip to hold control line wire in place. The wires may be glued between the body and the wing to keep the stress of flight from pulling the motor off its mount.

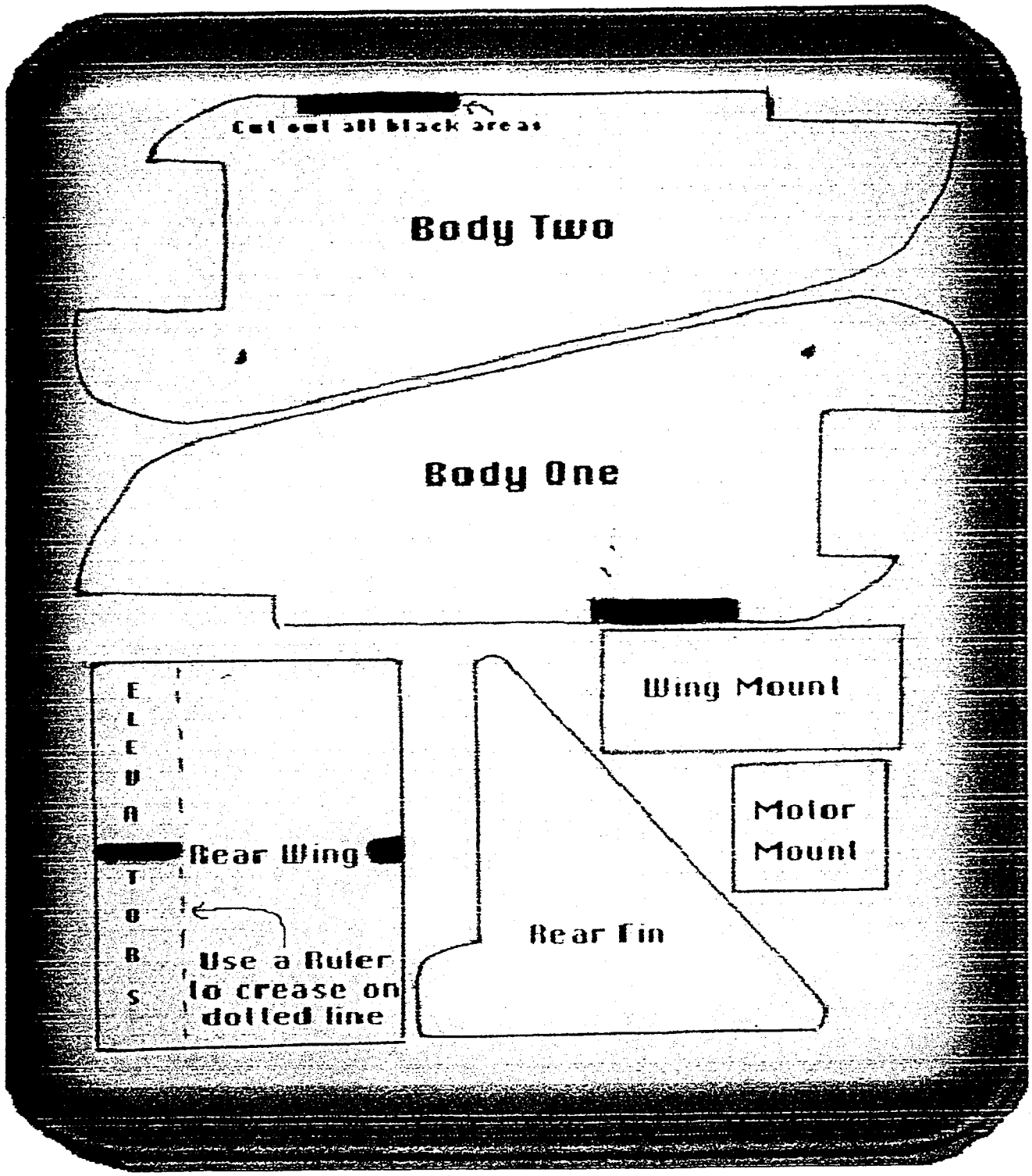
12. Plug control line into the power pole and “power up” your plane.

Scoring Rubric for Lab Report

4 **Student gave many examples of flight dynamics to support his/her hypotheses and made excellent conclusions about optimal Aspect Ratio and curvature needed to get maximum lift and short take-off time**

3 **Student gave some examples of flight dynamics to support his/her hypotheses and made good or excellent conclusions about optimal Aspect Ratio and curvature needed to get maximum lift and short take-off time**

2 **Student gave a few examples of flight dynamics to support his/her hypotheses and made some conclusions about optimal Aspect Ratio and curvature needed to get maximum lift and short take-off time**

1 **Student gave little or no examples of flight dynamics to support his/her hypotheses and made some conclusions about optimal Aspect Ratio and curvature needed to get maximum lift and short take-off time**

Picture 1: Styrofoam Template (actual size)