BIRD FLIGHT

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INTRODUCTION

The bird is, quite literally, a flying machine. Except for a few flightless species, flight is a dominant feature that permeates all aspects of the bird's anatomy, physiology, and ecology. The constraints of flight have had a very conservative influence on bird evolution. Consequently, among the 8700 species of living birds, there is little deviation from the basic avian form. Most of the differences between birds occur in those regions uninvolved with flight such as the beak and foot. The most diverse birds are found among the ratites which, having evolved flightlessness, have been freed from conforming to the aerodynamic form. In this lab you will learn what aspect ratio and wing loading are and how they are computed. In the latter half of the exercise you will experiment with variables that affect flight performance.

LEARNING OBJECTIVES

The student will:

- Review the morphology of the bird wing.
- Demonstrate quantitative differences between wing types.
- Compute aspect ratio and wing loading for wings of different species.
- Learn the relationship that exists between lift, air speed, and angle of attack.

MATERIALS

For each group of students:

3 wings (House Sparrow [*Passer domesticus*], Rock Dove [*Columba livia*], European Starling [*Sturnus vulgaris*])*
metric ruler
wind speed indicator
electric fan
double pan balance
stand and clamp
protractor
beaker, 500 ml capacity
water
11 x 17" paper marked off in cm grid

* The species indicated above require no federal permit and are easily obtained. Gull, hawk, duck, or owl wings work better due to their larger size but require appropriate permits.

PROCEDURE

For this exercise you will work in groups of 2-4 to complete each aspect of the lab. Use your textbook and the resource materials that have been provided to answer the questions.

Wing Morphology

Review the bone structure of the wing. Locate the humerus, radius, ulna, carpals, carpometacarpus, and the three digits.

Using the wings on the table locate the following regions or structures; remiges, elbow, primary feathers, wrist, secondary feathers, hand, alula.

Complete the following table:

Species	Number of primary feathers	Number of secondary feathers
____________________	________	_________
____________________	________	_________
____________________	________	_________
____________________	________	_________

Some birds have an elongated humerus. Remiges that arise along the humeral region of the forelimb are called ***tertiaries*** (or tertials). Do any of the wings before you possess tertiaries? _____

The ***aspect ratio*** is the ratio of the wing length to its width. Long narrow wings have a high aspect ratio. Sailplanes and albatrosses may have aspect ratios as great as 18:1.

Measuring in centimeters, determine the aspect ratio for each of the wings.

Species	length (cm)	width (cm)	Aspect Ratio (length/width)
______________________	_____	_____	_____
______________________	_____	_____	_____
______________________	_____	_____	_____
______________________	_____	_____	_____

The bird wing is an airfoil. The bones within the wing area form a V. The straight leading edge of the bird's wing is due to a strip of skin that stretches from the shoulder to the wrist. This strip of skin is called the ***patagium*** and forms the leading edge of the wing.

Imagine the wing in cross section. In the region below draw the wing in cross section in the region of the alula.

Camber refers to the thickness of the airfoil. Which of the wings before you has the greatest camber? ____________________

Wing Shape

Wings have been divided into four basic types: the elliptical wing, high-speed wing, slotted-high lift, and the high-aspect ratio wing. Consult your text for a comparison of each.

Sketch each of the wings before you and identify what type wing each is.

Species__________________ Species__________________

Species__________________

Wing loading is the ratio of weight and area. It is a measure of the amount of weight carried by the wings. Remembering that each bird has two wings (you will measure only one), how well does your wing loading compare to the wing loading recorded for the species? See reference books provided by your instructor.

Determine the surface area (square centimeters) of each wing by tracing the wing on paper and by counting the number the square centimeters. Record the number in the table below.

Species	Area (cm^2)	Body weight (grams)	grams/cm^2	Wing loading from table
______________________	_____	_____	______	______
______________________	_____	_____	______	______
______________________	_____	_____	______	______
______________________	_____	_____	______	______

Comparison of Lift

The bird generates lift both from the action of the beating wings as well as from the movement of air over and under the stationary wing as when the bird is gliding. In this lab we are going to determine the lift generated by the wing in moving air. We are going to vary the angle the wing makes to the oncoming air (angle of attack) and the speed of the air.

For this part of the lab you will use only one of the wings. Select a wing from those available. Take the bird wing and mount it on the stand as shown below (Figure 1). TAKE CARE SO AS TO NOT BREAK THE WING. Place the wing and stand on the balance and adjust the wing so it is level to the table top. On the other pan add enough water to the bottle so the weight of the wing and stand is exactly balanced with the scale reading zero grams (Figure 2).

Figure 1. Bird wing held in clamp and mounted on the stand..

Figure 2. Mounted wing on balance with equal weight of water.

Position the wing as nearly level as possible and directly in front of the fan. The fan should be approximately 0.5 meter away from the wing.

Turn the fan on to low speed. Record the wind speed at the leading edge of the wing following the directions given at the beginning of class using the wind speed indicator. (If necessary convert miles per hour to kilometers per hour using the following equation:

kph = mph x 0.62)

Use the balance to determine how many grams of lift are being generated by the wing. Record the data on the worksheet.

Turn the fan to medium speed and repeat the procedure. Record wind speed and grams of lift. Repeat for high speed.

After completing the three measurements (low, medium, high speed) change the angle of attack of the wing. Measure the new angle of attack by using the apparatus shown in Figure 3. Attach a protractor to a wooden ruler as shown. Tie a weight to a piece of string and tack the string to the base of the protractor and ruler at the zero point so that the string hangs at 90° when the ruled edge of the ruler is horizontal (i.e. on the surface of the lab table) with the protractor hanging down. To measure the angle of attack of the wing place the ruled edge of the ruler on the upper surface of the wing and read the angle at the point where the string crosses the protractor.

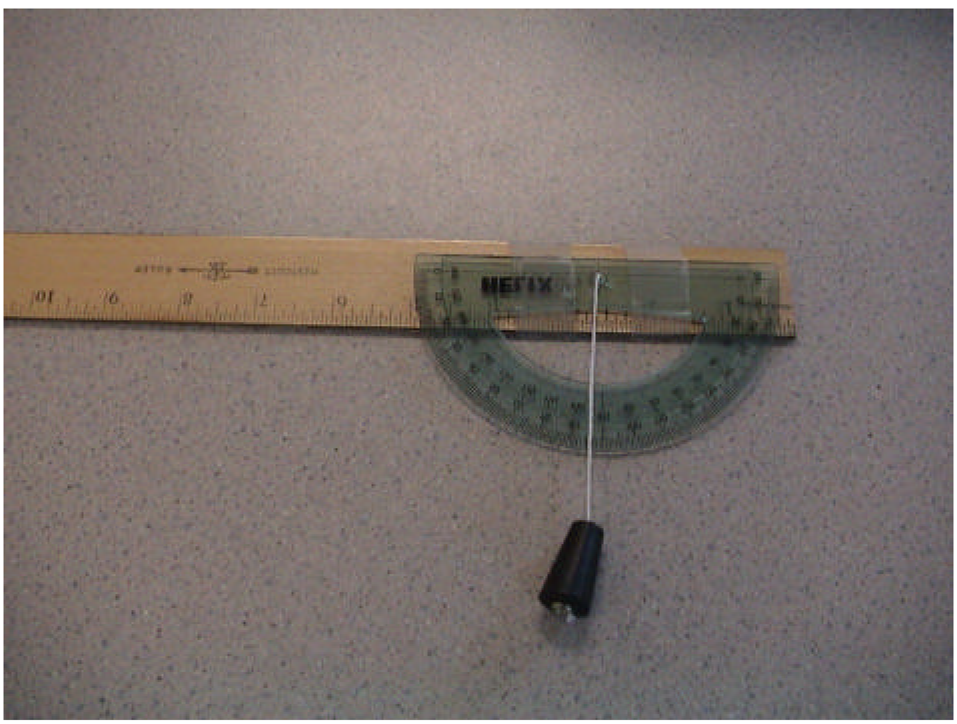

Figure 3. Protractor for measuring wing angle.

Determine the lift generating capacity of this same wing at this new angle of attack at each of the three wind speeds.

Record all your observations on the worksheet.

Using the graph paper provided, plot the three curves obtained.

WORKSHEET

Species used:____

Angle of Attack (degrees)	**Air Speed** (km/hr)	**Lift** (grams)
________	________	________
	________	________
	________	________
________	________	________
	________	________
	________	________
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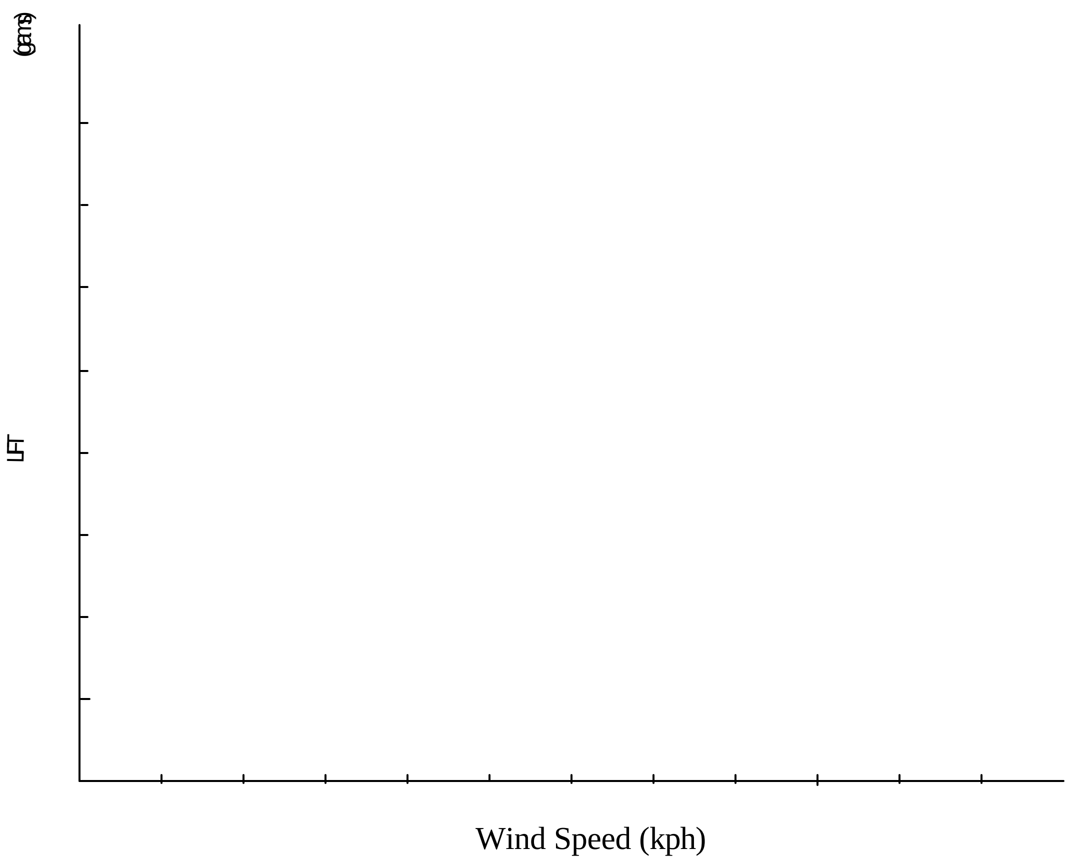

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