Know All the "Wright" Angles

In July of 1901, the Wright Brothers were at Big Kill Devil Hill in North Carolina for more tests on their glider. On one day in particular, July 27th, there were many unsuccessful launches. The glider did get into the air, but it would stall. The stall occurred under the same circumstances for each flight. It happened when the glider slowed its speed. When its speed slowed, the pilot would increase the wing angle to compensate and maintain lift. At a certain critical point when the angle was very steep, the airflow over the top of the wing would become turbulent. This meant that the wing stopped generating lift.

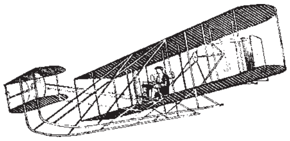
When the brothers returned to Dayton, Ohio, for the winter, they needed to perform some experiments on the angle of attack for the 1901 glider. They used their own wind tunnel to test airfoil shapes. They used data that they collected from those tests and others to solve their problems.

It is now 98 years later and a replica of the Wright Brothers' airplane, the Flyer, is mounted in the 40' x 80' wind tunnel at Ames Research Center. The researchers are concerned about the airplane's lift and drag for safe flight. The AIAA pilots have many questions concerning how the airplane will fly. Among other questions, they have these questions about angle of attack:

- Which angle of attack would give the glider the greatest amount of lift?
- What cruising angle would be the most efficient for flight?
- What is the stall angle for his glider?

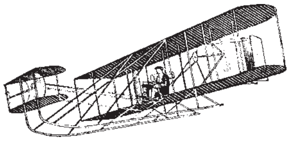
If you need a review of how to understand the wind tunnel test results, then read through the information from the "Know All the Angles" on the pages 2 - 10.

If you are comfortable in your understanding of the data gathered during wind tunnel test then go on to Activity Sheets #1 and #2 and help the AIAA pilots in answering their questions.



Wright *Flyer* Replica
Wind Tunnel Data Table

Run #	Point #	Alpha	Lift, w	Drag, w	CL, w	CD, w	L/D
43	4	-0.002	637.9	126.78	0.644	0.128	5.506
43	5	-4.001	326.72	108.69	0.3274	0.1089	3.1078
43	6	-1.999	501.53	113.76	0.4943	0.1121	4.7027
43	7	-1.999	513.84	113.4	0.5088	0.1123	4.849
43	8	0.0006	667.28	125.54	0.6711	0.1263	5.8659
43	9	1.9998	812.15	143.15	0.8102	0.1428	6.4151
43	10	3.9844	939.25	167.53	0.9369	0.1671	6.4306
43	11	5.9992	1053.2	196.86	1.0878	0.2033	6.2076
43	12	0.0006	677.65	125.77	0.6728	0.1249	5.9556
44	1	0.0006	650.52	117.25	0.6482	0.1168	6.1334
44	2	-4.001	327.87	107.79	0.3264	0.1073	3.146
44	3	-1.999	474.87	109.7	0.4729	0.1092	4.6033
44	4	#VALUE!	639.43	117.24	0.6392	0.1172	6.0127
44	5	1.9983	781.23	133.15	0.7713	0.1315	6.6302
44	6	3.9991	915.91	156.57	0.9235	0.1579	6.7413
44	7	5.9985	1044.6	186.31	1.0473	0.1868	6.5221
44	8	0.0006	644.5	117.09	0.6334	0.1151	6.0695



Know All the "Wright" Angles
Activity Sheet #1

Directions: Use the data table on page 2 to help AIAA pilots answer their questions.

1. For Run #43 looking at points #4 – 11, what is the difference in lift between the greatest weight and the least force?

2. For Run #44 looking at points #5 – 8, what is the difference in drag between the least weight and the greatest force?

3. Which angle of attack (alpha) overall generated the greatest amount of lift?

4. Which angle of attack (alpha) overall generated the least amount of drag?

5. Which angle of attack (alpha) overall generated the lowest positive L/D?

6. Which angle of attack (alpha) overall generated the greatest L/D?

Know All the "Wright" Angles
Activity Sheet #1 (continued)

7. For Run #43, looking at Points # 1-12, find the greatest L/D. __________

8. For Run #43, looking at Points #1-12, give the number following the greatest L/D. __________

9. Using the information from questions 7 and 8, what is the angle of attack (alpha) at which the airplane is not generating as much lift as it was before?

10. From Run #43, Point #4 to Run #44, Point 8, which angle of attack (alpha) generates the greatest CL?

11. From Run #43, Point #4 to Run #44, Point 8, which angle of attack (alpha) generates the lowest CL?

12. From Run #43, Point #4 to Run #44, Point 8, which angle of attack (alpha) generates the greatest CD?

13. From Run #43, Point #4 to Run #44, Point 8, which angle of attack (alpha) generates the lowest CD?

14. Overall, which angle of attack (alpha) do you think is the stall angle? Explain your reasoning. (Hint: Look over your answers for questions 7 – 12.)

Know All the "Wright" Angles
Activity Sheet #1 - KEY

Directions: Use the data table on page 2 to help AIAA pilots answer their questions.

1. For Run #43 looking at points #4 – 11, what is the difference in lift between the greatest weight and the least force?

1053.20	*Greatest*
-326.72	*Least*
726.48	*Difference*

2. For Run #44 looking at points #5 – 8, what is the difference in drag between the least weight and the greatest force?

186.31	*Greatest*
117.09	*Least*
69.22	*Difference*

3. Which angle of attack (alpha) overall generated the greatest amount of lift?

5.9992 from Run #43, Point #11

4. Which angle of attack (alpha) overall generated the least amount of drag?

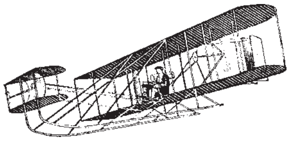
Run #43, Point #3, -0.002 drag was 10.374

5. Which angle of attack (alpha) overall generated the lowest positive L/D?

-4.001 from Run #43, Point #5 generated L/D of 3.1078

6. Which angle of attack (alpha) overall generated the greatest L/D?

3.9991 from Run #44, Point #6 generated L/D of 6.7413



Know All the "Wright" Angles
Activity Sheet #1 (continued) - KEY

7. For Run #43, looking at Points # 1-12, find the greatest L/D. __6.4306__

8. For Run #43, looking at Points #1-12, give the number following the greatest L/D. __6.2076__

9. Using the information from questions 7 and 8, what is the angle of attack (alpha) at which the airplane is not generating as much lift as it was before?

   5.9992 (or 6.0) from Run #43, Point #1

10. From Run #43, Point #4 to Run #44, Point 8, which angle of attack (alpha) generates the greatest CL?

    5.9992 from Run #43, Point #1

11. From Run #43, Point #4 to Run #44, Point 8, which angle of attack (alpha) generates the lowest CL?

    Run #44, Point #2, 0.3264

12. From Run #43, Point #4 to Run #44, Point 8, which angle of attack (alpha) generates the greatest CD?

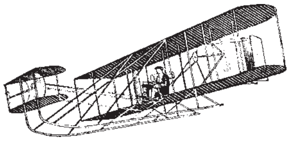
    Run #43, Point #11, 0.2033

13. From Run #43, Point #4 to Run #44, Point 8, which angle of attack (alpha) generates the lowest CD?

    Run #44, Point #2, 0.1073

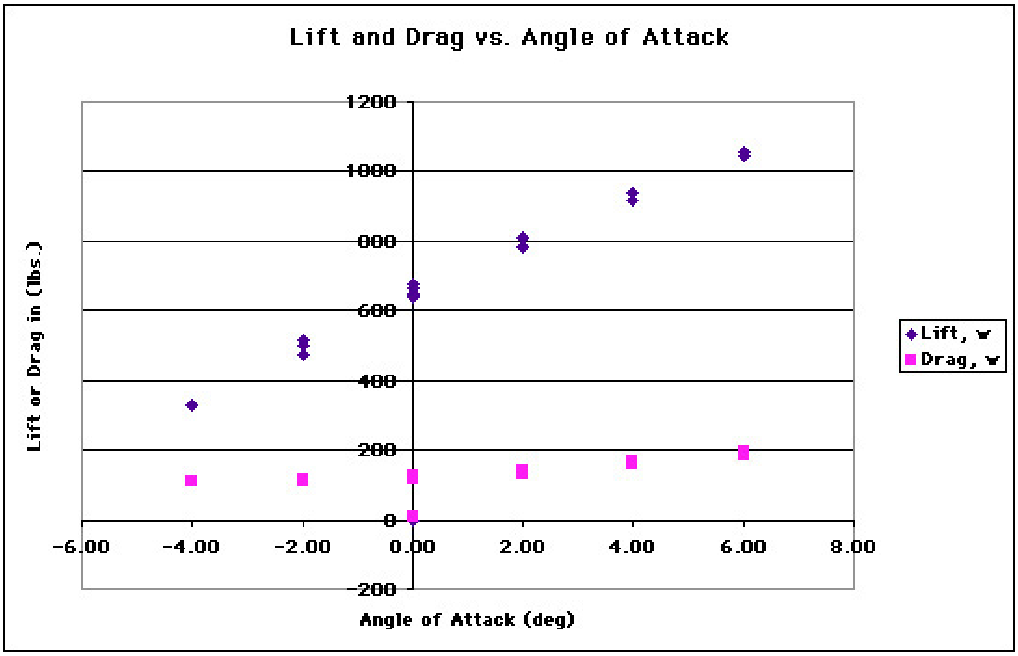
14. Overall, which angle of attack (alpha) do you think is the stall angle? Explain your reasoning. (Hint: Look over your answers for questions 7 – 12.)

    The angle between alpha 3.9844 and 5.9992 because lift is not increasing as much as before and drag is increasing a lot, and the L/D drops almost 0.2.



Know All the "Wright" Angles
Activity Sheet #2

Directions: Use the graph below to help the AIAA pilots answer their questions. This is a graph showing the data collected on the *Flyer* replica. It displays the lift and the drag at different angles of attack of the *Flyer* for different runs.



1. On the graph above, circle the point at which the most lift is being generated.

   A. How many pounds of lift are being generated? ____________

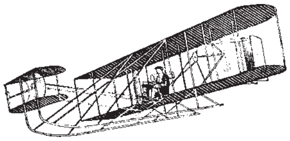
   B. What is the angle of attack? ____________

2. On the graph above, draw a box around the point at which the most drag is being generated.

   A. How many pounds of drag are being generated? ____________

   B. What is the angle of attack? ____________

3. Give the angle of attack at which 800 pounds of lift are being generated?



Know All the "Wright" Angles
Activity Sheet #2 (continued)

Directions: Use the graph from page 7 to help the AIAA pilots answer their questions.

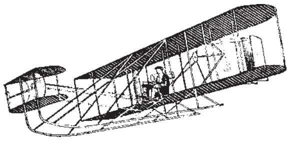
4. At which angle of attack does drag begin to steadily increase?

5. Contrast the increase in lift to the increase in drag.

6. What do you think your answer to question #5 has to do with the Flyer's lift capability?

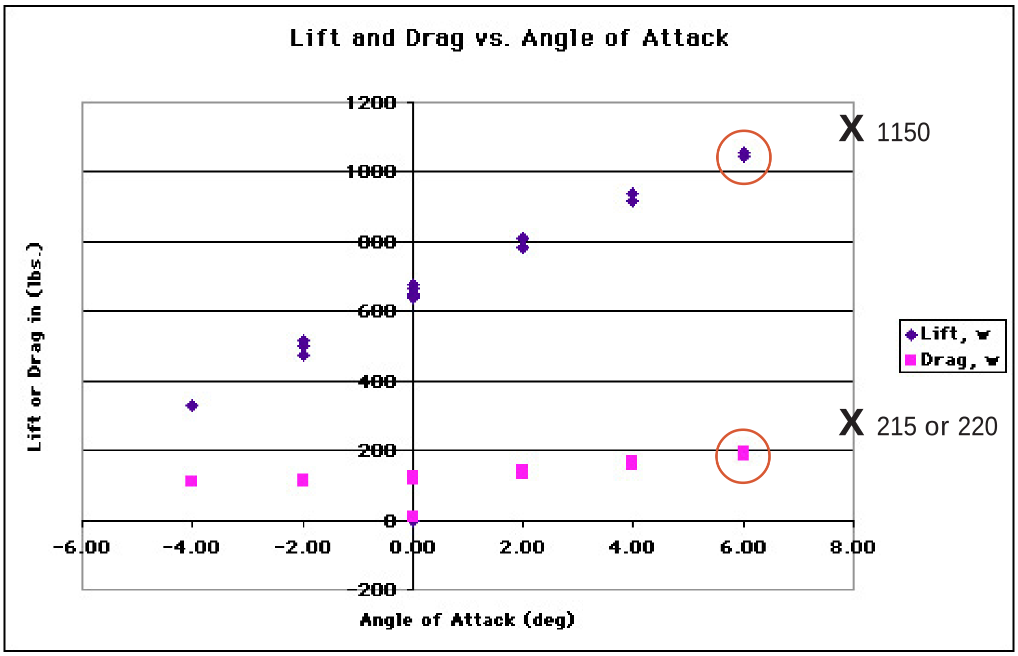
7. A good cruise angle is one in which the design has the greatest difference between lift and drag. Doing some subtraction, calculate which angle of attack would most likely be the most efficient cruise angle? (Hint: you don't have to subtract the drag from lift of each angle of attack. Narrow the field, by looking for the biggest gap between lift and drag and then doing some subtraction.)

8. If lift and drag continued to increase at the same rate, predict the lift and drag in pounds and place 2 "x"'s on the graph at each point.



Know All the "Wright" Angles
Activity Sheet #2 - KEY

Directions: Use the graph below to help the AIAA pilots answer their questions. This is a graph showing the data collected on the *Flyer* replica. It displays the lift and the drag at different angles of attack of the *Flyer* for different runs.



1. On the graph above, circle the point at which the most lift is being generated.

   A. How many pounds of lift are being generated? *about 1050*

   B. What is the angle of attack? *6°*

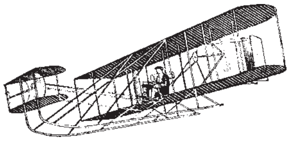
2. On the graph above, draw a box around the point at which the most drag is being generated.

   A. How many pounds of drag are being generated? *200 lbs*

   B. What is the angle of attack? *6°*

3. Give the angle of attack at which 800 pounds of lift are being generated.

   2°



Know All the "Wright" Angles
Activity Sheet #2 (continued) - KEY

Directions: Use the graph from page 7 to help the AIAA pilots answer their questions.

4. At which angle of attack does drag begin to steadily increase?

   2°

5. Contrast the increase in lift to the increase in drag.

   The increase in lift appears to increase at a steady rate of about 150 pounds for each 2° increase in the angle of attack. Whereas the increase in drag rises about 15-20 pounds for each 2° increase in the angle of attack.

6. What do you think your answer to question #5 has to do with the Flyer's lift capability?

   It appears that because the Flyer's lift increases at a rate greater than drag, the Flyer's wings generate more than a sufficient amount of lift at these angles of attack.

7. A good cruise angle is one in which the design has the greatest difference between lift and drag. <u>Doing some subtraction, calculate which angle of attack would most likely be the most efficient cruise angle</u>? (Hint: you don't have to subtract the drag from lift of each angle of attack. Narrow the field, by looking for the biggest gap between lift and drag and then doing some subtraction.)

   6° angle of attack ~ 1050 lbs. lift
   ~ <u>-200 lbs.</u> drag
   850 lbs. lift

   4° angle of attack ~ 800 lbs. lift
   ~ <u>-150 lbs.</u> drag
   650 lbs. lift

8. If lift and drag continued to increase at the same rate, predict the lift and drag in pounds and place 2 "x"'s on the graph at each point.

   drag = ~215 lbs. or ~220 lbs.
   lift = ~ 1150 lbs