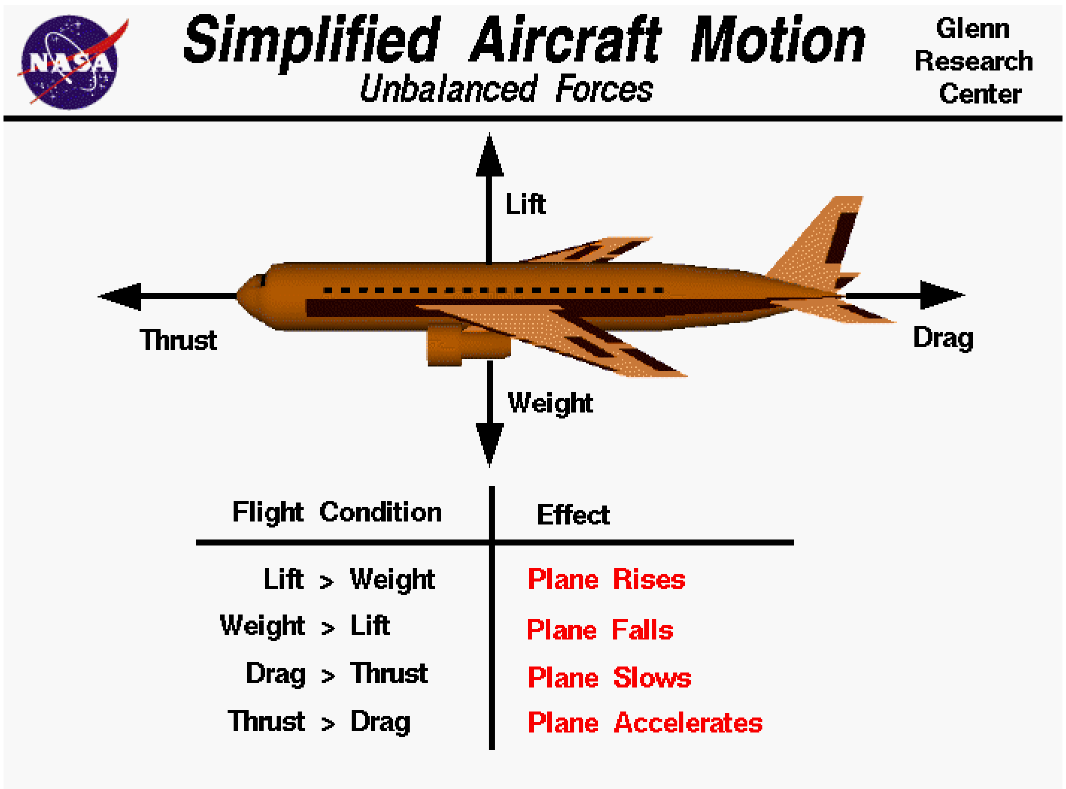
Aerospace Assignment

Physical Science and Technology

This assignment is REQUIRED for all students not attending the field trip to Evergreen Aviation on Wednesday, 5/15/2013. Please answer all questions on a separate sheet of paper, in your own words. Show your work where appropriate. Your work will be graded on accuracy and evidence of effort. This is an INDIVIDUAL assignment. It is due at the end of the period today.

Part I:



This slide shows some rules for the simplified motion of an aircraft. By **simplified motion** we mean that some of the four forces acting on the aircraft are balanced by other forces and that we are looking at only one force and one direction at a time. In reality, this simplified motion doesn't occur because all of the forces are interrelated to the aircraft's speed, altitude, orientation, etc. But looking at the forces ideally and individually does give us some insight and is much easier to understand.

In an ideal situation, an airplane could sustain a constant speed and level flight in which the weight would be balanced by the lift, and the drag would be balanced by the thrust. The closest example of this condition is a cruising airliner. While the weight decreases due to fuel burned, the change is very small relative to the total aircraft weight. In this situation, the aircraft will maintain a constant cruise velocity as described by Newton's first law of motion.

If the forces become unbalanced, the aircraft will move in the direction of the greater force. We can compute the acceleration which the aircraft will experience from Newton's second law of motion

$$F = m * a$$

Where **a** is the acceleration, **m** is the mass of the aircraft, and **F** is the net force acting on the aircraft. The net force is the difference between the opposing forces; lift minus weight, or thrust minus drag. With this information, we can solve for the resulting motion of the aircraft.

If the weight is decreased while the lift is held constant, the airplane will rise:

Lift > Weight - Aircraft Rises

If the lift is decreased while the weight is constant, the plane will fall:

Weight > Lift - Aircraft Falls

Similarly, increasing the thrust while the drag is constant will cause the plane to accelerate:

Thrust > Drag - Aircraft Accelerates

And increasing the drag at a constant thrust will cause the plane to slow down:

Drag > Thrust - Aircraft Slows

(From http://www.grc.nasa.gov/WWW/K-12/airplane/smotion.html)

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1. What is the smallest angle in degrees between the lift and drag forces?

   (a) 0^o (b) 90^o (c) 180^o (d) 270^o (e) 360^o

2. What is the smallest angle in degrees between the weight and lift forces?

   (a) 0^o (b) 90^o (c) 180^o (d) 270^o (e) 360^o

3. What is the smallest angle in degrees between the thrust and drag forces?

   (a) 0^o (b) 90^o (c) 180^o (d) 270^o (e) 360^o

4. What is the smallest angle in degrees between the weight and thrust forces?

   (a) 0^o (b) 90^o (c) 180^o (d) 270^o (e) 360^o

5. When an airplane (or any object) is moving at a constant speed, the forces acting on the airplane must be

   (a) unbalanced, which means that the total force is not zero

   (b) balanced, which means that the total force is zero

A fighter jet is flying at 37,000 feet with a constant speed of 1,310 km/h. The jet has a weight of 110,000 N and its engines provide a thrust of 106,752 N (using afterburners).

6. What is the jet's height (altitude) in meters?

$$\text{height} = \frac{37{,}000\ \text{ft}}{1} \times \frac{\_\_\_\_\_\_\ \text{in}}{1\ \ \text{ft}} \times \frac{\_\_\_\_\_\_\ \text{cm}}{\text{in}} \times \frac{\_\_\_\_\_\_}{\_\_\_\_\_\_}$$

(a) 1.13×10^8 m (b) 61,248 m (c) 8,679 m (d) 356 m (e) 11,277.6 m

7. What is the jet's mass? [**Hint:** Use $F = ma_g = W$, where $a_g = 9.8\ m/s^2$.]

(a) 520,120 kg (b) 11,224.49 kg (c) 3,527 kg (d) 614,853 kg (e) 215 kg

8. How much lift force is being applied to the jet?

(a) 512,128 N (b) 5,634 N (c) 110,000 N (d) 9,935 N (e) 106,752 N

9. If the jet engines are creating a thrust of 106,752 N, what is the drag force applied to the jet?

(a) 512,128 N (b) 5,634 N (c) 110,000 N (d) 9,935 N (e) 106,752 N

Suppose the jet engines are providing a thrust of 100,102 N while the drag force is only 90,167 N.

10. What is the total unbalanced (or net) force on the jet?

(a) 512,128 N (b) 5,634 N (c) 110,000 N (d) 9,935 N (e) 106,752 N

11. What will be the jet's acceleration?

(a) $0.89\ m/s^2$ (b) $4.35\ m/s^2$ (c) $0.36\ m/s^2$ (d) $4{,}253\ m/s^2$ (e) $65.3\ m/s^2$

12. If the jet is cruising at 223.47 m/s and accelerates at 0.25 m/s^2 for 1,530 seconds, what is the jet's final speed?

(a) 401.28 m/s (b) 605.97 m/s (c) 731.67 m/s (d) 634,521.6 m/s (e) 3,452 m/s

13. Using the data from the previous problem, calculate how far the jet traveled while it accelerated during the 1,530 seconds.

(a) 401.28 m (b) 605.97 m (c) 731.67 m (d) 634,521.6 m (e) 3,452 m

14. If the jet cruised at a speed of 1,310 km/h for 2.53 hours, how far did it travel?

(a) 517.79 km (b) 4,639.00 km (c) 218.42 km (d) 6,547.23 km (e) 3,314.30 km

(From http://www.grc.nasa.gov/WWW/K-12/BGA/Monroe/aircraft_motion_1_act.htm)

Part II:

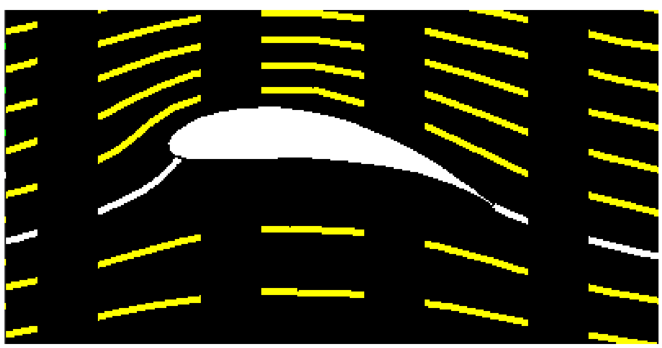
Velocity Effects on Aerodynamic Forces

Glenn Research Center

F = Force

L = Lift

D = Drag



V = Velocity

Aerodynamic force is related to square of velocity.

F = Constant x V^2

then

L = Constant x V^2

Double the Velocity --> Quadruple the Lift

and

D = Constant x V^2

Double the Velocity --> Quadruple the Drag

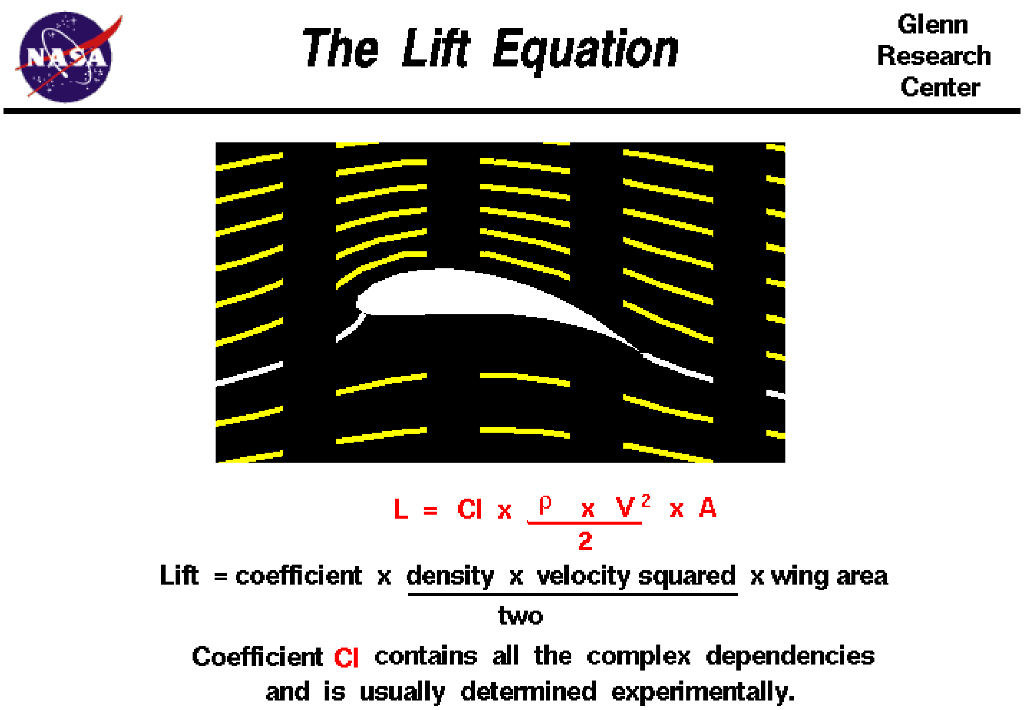
Lift is created by deflecting a flow of air and drag is generated on a body in a wide variety of ways. From Newton's second law of motion, the **aerodynamic forces** on the body (lift and drag) are directly related to the change in momentum of the fluid with time. The **fluid momentum** is equal to the mass times the velocity of the fluid. Since the air moves, defining the mass gets a little tricky and aerodynamicists usually relate the effect of mass on lift and drag to the air density. The mathematical derivation for this conversion is given on another slide dealing with momentum effects on lift. As a result of this derivation, we find that lift and drag depend on the **square of the velocity**.

The velocity used in the lift and drag equations is the relative velocity between an object and the flow. Since the aerodynamic force depends on the square of the velocity, doubling the velocity will quadruple the lift and drag.

Let's investigate the dependence of lift on velocity using a Java simulator: Click here to run the simulator

As an experiment, set the velocity to 50 mph and note the amount of lift. Now double the velocity to 100 mph. What is the value of the lift? How does it compare to the previous measurement?

(From http://www.grc.nasa.gov/WWW/K-12/airplane/vel.html)



15. Identify each letter in the lift equation and list acceptable units for each quantity.

16. Use Wikipedia (http://en.wikipedia.org/wiki/Boeing_747), or a search engine, to find information about the Boeing 747. What is its wing area?

17. If the Boeing 747 above is cruising at 940 km/h, the density of the air is 1.20 g/L, and the lift coefficient is 1, what is the lift ?

18. Use Wikipedia (http://en.wikipedia.org/wiki/Boeing_777), or a search engine, to find information about the Boeing 777. What is its wing area?

19. If the Boeing 777 is cruising at the same velocity under the same conditions as the 747 above,

what is its lift?

20. Look up the DC-8 on Wikipedia (http://en.wikipedia.org/wiki/DC-8), or a search engine. What is its wing area?

21. What is the DC-8's cruising velocity?

22. If the air density is 1.26 g/L and the lift coefficient is 1.5, what is the lift of the DC-8?

23. Find the F/A-18A Hornet on Wikipedia (http://en.wikipedia.org/wiki/F-18), or use a search engine. What is its wing area?

24. What is the F/A-18A's lift while it flies at 700 mph, the air density is 1.31 g/L, and the lift coefficient is 1.8?

(From http://www.grc.nasa.gov/WWW/K-12/BGA/Sheri/the_lift_equation_act.htm)