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The wings provide lift by creating a situation where the pressure above the wingis lower than the pressure below the wing. Since the pressure below the wing is higherthan the pressure above the wing, there is a net force upwards.

To create this pressure difference, the surface of the wing must satisfy one or both ofthe following conditions. The wing surface must be: Cambered (curved); and/or Inclined relative to the airflow direction.Several airfoils are shown in Figure 3. However, the airfoils shown in Figure 3 areuseless without viscosity.

Viscosity is essential in generating lift. The effects of viscosity lead to theformation of the starting vortex (see Figure 4), which, in turn is responsible forproducing the proper conditions for lift.

As shown in Figure 4, the starting vortex rotates in a counter-clockwise direction. Tosatisfy the conservation of angular momentum, there must be an equivalent motion to opposethe vortex movement. This takes the form of circulation around the wing, as shown inFigure 5. The velocity vectors from this counter circulation add to the free flow velocityvectors, thus resulting in a higher velocity above the wing and a lower velocity below thewing (see Figure 6).

One method is with the Bernoulli Equation, which showsthat because the velocity of the fluid below the wing is lower than the velocity of thefluid above the wing, the pressure below the wing is higher than the pressure above thewing.

A second approach uses Euler''sEquations (which the Bernoulli equation is derived from) across the streamlines.Due to the curvature of the wing, the higher velocities and acceleration over the top ofthe wing requires a pressure above the wing lower than the ambient pressure.

Thus, using either of the two methods, it is shown that the pressure below the wing ishigher than the pressure above the wing. This pressure difference results in an upwardlifting force on the wing, allowing the airplane to fly in the air.

Take point 1 to be at a point on the streamline far in front of the wing (see Figure7). Here, the pressure is P1 = Pambient. Take point 2 to beat a point above the curved surface of the wing, outside of the boundary layer. It isassumed that compared to the other terms of the equation, gz1 and gz2are negligible (i.e. the effects due to gravity are small compared to the effects due tokinematics and pressure). Thus, Equation 1 becomes:

For the second case, take point 1 to be again at a point on the streamline in front ofthe wing. Since the values for Pambient and vambientare the same as for the first case, the constant from Equation 2 is also assumed to be thesame. Take point 2 to be at a point below the wing, outside of the boundary layer. Withthe same assumptions as in the first case, Equation 1 and 2 become:

Since the velocity of the fluid below the wing is slower than the velocity of the fluidabove the wing, to satisfy Equation 3, the pressure below the wing must be higher than thepressure above the wing.

In a qualitative look at Euler''s Equations, the movement of the fluid flow around thecurved upper surface of the wing may be likened to that of a car going around a bend.3As you will learn or have already learned in freshman physics, when the car turns, a forcemust accelerate the car towards the center of the turn (see Figure 8). Similarly, as thefluid particle follows the cambered upper surface of the wing, there must be a forceacting on that little particle to allow the particle to make that turn.

This force comes from a pressure gradient above the wing surface. Starting at thesurface of the wing and moving up and away from the surface, the pressure increases withincreasing distance until the pressure reaches the ambient pressure. Thus, a pressuregradient is created, where the higher pressures further along from the radius of curvaturepush inwards towards the center of curvature where the pressure is lower, thus providingthe accelerating force on the fluid particle.