DATE: _____

*Principles of Flight

Objectives	The learner develops an understanding of the principles of flight. They understand why an airplane is designed the way it is, as well as the forces acting on airplanes, and how to apply that knowledge to the aircraft in flight
Elements	1. Bernoulli's Principle, Newton's Laws 2. Forces of Flight 3. Airfoils 4. Lift 5. Basic Airfoil Design 6. Stability, Maneuverability and Controllability 7. Turning Tendencies 8. Wingtip Vortices 9. Dangers of Vortices
Schedule	1. Discuss Objectives :5 2. Review Material - Physiology, IMSAFE, Human Factors 5: 3. Development :50 4. Conclusion 5: 5. Total Time 1.8
Equipment	1. White board and markers 2. References 3. Model Airplane
Instructor Actions	1. Discuss Lesson objectives 2. Present Lecture 3. Ask and Answer Questions 4. Assign Homework
Student Actions	1. Participation in discussion 2. Take notes 3. Ask and respond to question
Completion Standards	The learner understands the principles of flight and can answer questions regarding lesson concepts. Learner can reciprocate simplified answers of turning tendencies, describe stability and the relationship between maneuverability and controllability. Will review before next lesson!

Introduction:

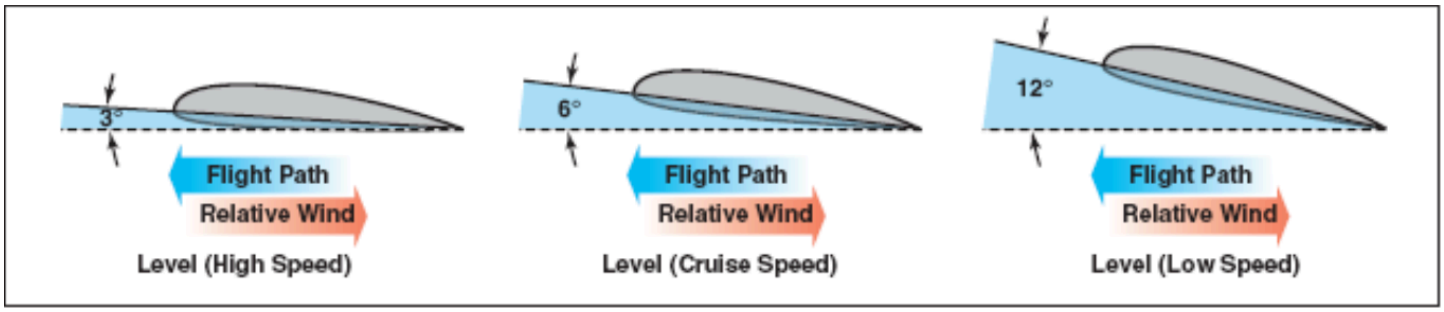
When becoming a pilot, it's not important to learn the rocket science behind aerodynamics and science. Though a competent pilot must have a well-founded understanding of the forces which act on the airplane, and the advantageous use of these forces, as well as operating limitations of the particular airplane.

DATE: _____

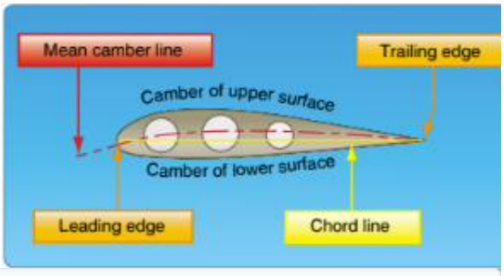
1. **Newton's Three Laws of Motion**
    i. Newton's 1st Law: A body as rest tends to stay at rest, and a body in motion tends to stay in motion
    ii. Newton's 2nd Law: When a body is acted upon by a constant force, its resulting acceleration is inversely proportional to the mass of the body and is directly proportional to the applied force / Force = Mass x Acceleration
    iii. Newton's 3rd Law: For every action, there is an equal and opposite reaction
2. **Bernoulli's Principle**
    i. As the velocity of a fluid (air) increases, its internal pressure decreases
3. **Forces of Flight**
    a. Overview
        i. Lift - The upward force created by the effect of airflow as it passes over and under the wing
        ii. Weight - Opposes lift, and is caused by the downward pull of gravity
        iii. Thrust - The forward force which propels the airplane through the air
        iv. Drag - Opposes thrust, and is the backward, or retarding force, which limits the speed of the airplane
        v. Terminology:
            1. Chord Line: The imaginary straight line join the leading and trailing edge of the wing
            2. Relative Wind: The direction of movement of the wind relative to the aircraft's flight path. It is opposite the aircraft's flight path and irrespective of the angle of attack
                a. EX. Straight and level slow flight and high-speed flight have the same relative wind
            3. Angle of Attack (AoA): The angle between the chord line and the relative wind
    b. Lift - Opposes weight
4. **Airfoils and Lift**
    i. An airfoil is any surface, such as a wing that provides aerodynamic force when it interacts with a moving stream of air
    ii. How is the Lift Made?
        1. Air has Streamlines and Streamtubes:
            a. Streamlines become compressed on top edge of wing, creating streamtube which creates low pressure that PULLs wing up
    iii. A backward-downward flow of air is also generated from the top surface of the wing, adds an upward force on the wing (newton's 3rd law)
    iv. Air flow hits bottom of wing when inclined adding small upward force
    b. Pilot Control of Lift
        i. Lift Equation, Lift = 1/2pCLV^2S
            1. P = Rho or pressure constant
            2. Cl = Coefficient of Lift
            3. V= Velocity
            4. S = Surface Area

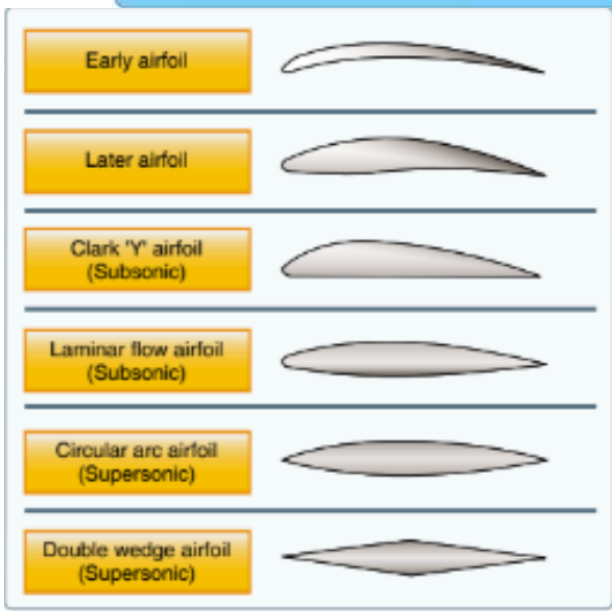
DATE: _____

ii. Amount of lift can be changed with the Angle of Attack, airspeed or changing the shape of the wing with flaps
iii. The faster a wing moves through the air, the more lift is produced
1. Lift is proportional to the square of the airspeed



5. **Airfoil Design** - Okay so we've talked about all these different forces, how and why the act. Let's look at some visuals of what we actually just discussed. Its gibberish if you can't visualize and understand it
   a. Airfoil: A structure designed to obtain a reaction upon it's surface from the air through which it moves or that moves past such a structure
   b. Terminology (Student action: Write dis DOWN)
      i. Camber - Curvature of the upper/ lower surface
      ii. Leading/Trailing Edge- Generally rounded leading edge, narrow and tapered trailing edge
      iii. Chord Line - Straight line drawn through the airfoil profile connecting the leading edge and trailing edge
      iv. Mean Camber Line - Drawn line equidistant at all points from the upper and lower surfaces

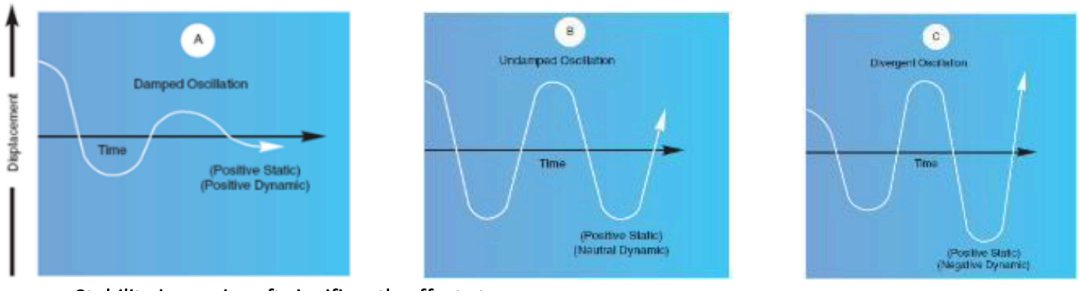




6. **Stability, Maneuverability and Controllability**
   a. Stability - The inherent quality of an airplane to correct for conditions that may disturb its equilibrium
      i. Primarily a design characteristic
      ii. The more stability, the easier to fly, but too much results in difficulty maneuvering
   b. Two Types of Stability: Static and Dynamic
      i. Static Stability (SS)
         1. SS: *The Initial Tendency* - Aircraft's initial response when disturbed from a condition
            a. Positive SS: Aircraft tends to return to original state
            b. Negative SS: Aircraft tends to continue away from original state
            c. Neutral SS: Aircraft tends to remain in new condition
      ii. Dynamic Stability (DS)

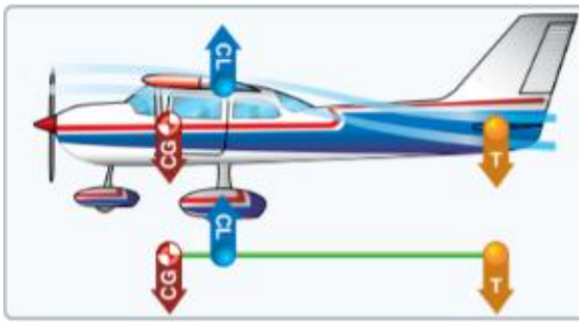
DATE: _____

1. SS refers to the initial tendency, DS refers to the aircraft response over time when disturbed



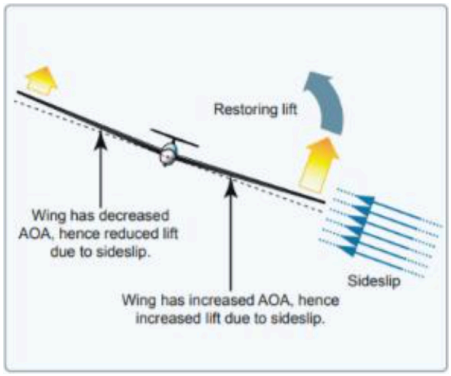
c. Stability in an aircraft affects two areas:
   i. Controllability - Capability of the aircraft to respond to the pilot's control, especially in regard to flight path and altitude
   ii. Maneuverability - Quality of the aircraft that permits it to be maneuvered easily and to withstand stresses imposed by maneuvers
      1. Governed by weight, inertia, size and location of flight controls, structural strength and power plant

d. Longitudinal Stability - About the lateral axis (Pitch)



   i. Relation of the wing and tail moments must be balanced to ensure LS
   ii. LS, or instability is depended on 3 factors
      1. Location of the wing in relation to the CG, CG is usually ahead of the wing, the nose down tendency is counteracted by tail down force
      2. More tail down force is needed for a CG located more forward - This adds longitudinal stability since the nose heaviness makes it more difficult to raise the nose and the additional tail down force makes it difficult to pitch down
      3. If CG if further aft, the plane becomes less stable in pitch
         a. Tail must exert upward force so the nose doesn't pitch up, extremely dangerous situation

e. Lateral Stability - About the longitudinal axis (Roll)



   i. Effected by Dihedral, Sweepback, Keel Effect, Weight Distribution
      1. Keel effect - depends on the action of relative win on the side area of fuselage,

f. Directional Stability - About the vertical axis (Yaw)

   i. Affected by area of vertical fin, and sides of fuselage aft of CG
   ii. Weathervane action - must have greater area aft of CG

iii. Vertical Fin action of directional stability if obvious, acts like a feather on an arrow

7. Turning Tendencies

a. Four turning tendencies of propeller, or rotating engines

b. Torque, P-Factor, Corkscrew-Slipstream, Gyroscopic Tendency

i. Torque - newton's 3rd law, as engine parts/propeller rotate one direction, an equal force is in the opposite, acts around the longitudinal axis (air)

ii. During takeoff, torque is attempting to roll the airplane left, adding friction and causing a turn to the left, **corrected** with RIGHT RUDDER and aileron inputs

c. P-Factor (Asymmetric loading)

i. On a prop and more apparent at high AOAs the thrust of the downward moving side of the prop is less than the upward moving right side of the prop, the prop is an airfoil in itself and greater velocity, greater lift

ii. On almost all single engines, the downward swinging side of prop is the Right side if looking out the cockpit, thus more thrust being created on the right side of the prop leading to a left turning tendency

iii. **Corrected** with coordinated rudder and aileron inputs

d. Corkscrew-Slipstream Effect

i. The high-speed rotation of the propeller sends the air in a corkscrew spiraling around the fuselage and hitting the vertical stabilizer from the left adding a left yawing moment to the airframe, more noticeable at high prop speeds but low forward speed, corkscrew is more aggressive

ii. Also creates a rolling moment to the right and may counteract torque to an extent

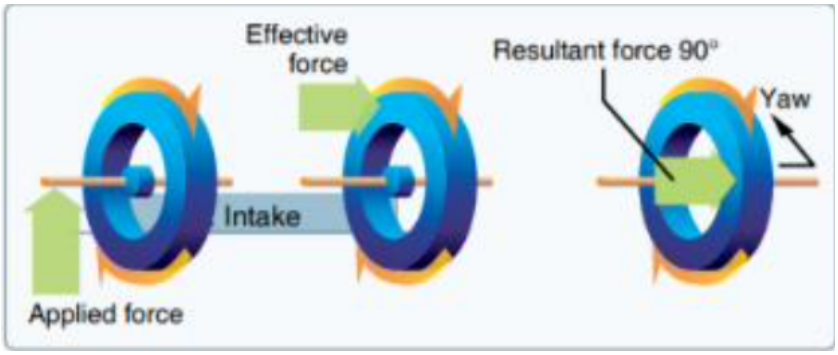
iii. **Corrected** with coordinated rudder and aileron inputs and most pronounced in takeoffs and climbs

e. Gyroscopic Action - Two fundamental principles of gyroscopes

i. Rigidity in Space (Not applicable to this discussion, used in attitude and heading indicators)

ii. Precession - The resultant action of a spinning rotor when a force is applied to its rim

1. When a force is applied to a gyroscope, it takes effect 90 degrees ahead of and in the direction of the turn
2. Causes a pitch moment, yaw moment or a combination of the two.
3. Most often occurs on tailwheel aircraft when the tail is raised during takeoff roll
4. **Corrected** with proper elevator and rudder pressures to prevent undesired pitch and yaw



8. Wingtip Vortices

a. Spiraling air - outward and upward from wingtips. Created when wing is creating lift
b. Wake Turbulence can be hazardous to any aircraft lighter than the generating aircraft, can result in major structural damage, inducing rolling making the aircraft uncontrollable
c. Behavior and Avoidance:
    i. Behavior of vortices - Sink a rate of several hundred fpm, slowing and diminishing the farther behind they get - Crosswinds will decrease lateral movement of the upwind vortex and increase movement of the downwind vortex, tailwind can move vortex into touchdown zone
    ii. Avoidance of vortices - Minimize the chance of flying through another aircrafts wake:
        1. Takeoff: Takeoff prior to the takeoff point of the preceding aircraft and attempt to climb above and upwind (if able) of their flight path
        2. Enroute: Avoid flying through another aircrafts flight path
            a. Avoid following another aircraft on similar path within 1000’ below
        3. Landing: Stay above the downtown point of preceding aircraft, and land past their touchdown point

Conclusion: Review the main points quickly
The competent pilot must have well-founded knowledge of the forces which action on the airplane, and the advantageous use of these forces, as well as the operating limitations of the airplane