Sub module 8.3 - Theory of flight

8.3.1 RELATIONSHIP BETWEEN LIFT, WEIGHT, THRUST AND DRAG

- *Gravity* is the pulling force that tends to draw all bodies toward the center of the earth. The Center of Gravity (CG) may be considered as a point at which all the weight of the aircraft is concentrated. If the aircraft were supported at its exact CG, it would balance in any attitude. Note that the CG is of major importance in an aircraft, for its position has a great bearing upon stability.

- The location of the CG is determined by the general design of each particular aircraft. The designers determine how far the Center of Pressure (CP) will travel. They then fix the CG forward of the center of pressure for the corresponding flight speed in order to provide an adequate restoring moment to retain flight equilibrium.

- Weight has a definite relationship to lift. This relationship is simple, but important in understanding the aerodynamics of flying.

- Lift is the upward force on the wing acting perpendicular to the relative wind. Lift is required to counteract the aircraft's weight (which is caused by the force of gravity acting on the mass of the aircraft).

- This weight (gravity) force acts downward through the airplane's CG. In stabilized level flight, when the lift force is equal to the weight force, the aircraft is in a state of equilibrium and neither gains nor loses altitude.

- If lift becomes less than weight, the aircraft loses altitude. When lift is greater than weight, the aircraft gains altitude.

✓ LIFT

- The pilot can control lift. Any time the control yoke or stick is moved fore or aft, the Angle of Attack (AOA) is changed.
- As the AOA increases, lift increases (all other factors being equal). When the aircraft reaches the maximum AOA, lift begins to diminish rapidly.
- This is the stalling AOA, known as Cl-max critical AOA. Examine in *Sub-Module 02* and note how the Cl increases until the critical AOA is reached, then decreases rapidly with any further increase in the AOA.
- Before proceeding further with the topic of lift and how it can be controlled, velocity must be interjected. The shape of the wing (or rotor) cannot be effective unless it continually keeps "attacking" new air.

- An aircraft cannot not continue to travel in level flight at a constant altitude and maintain the same AOA if the velocity is increased.

- The lift would increase and the aircraft would climb as a result of the increased lift force. Therefore, to maintain the lift and weight forces in balance, and to keep the aircraft straight and level (not accelerating upward) in a state of equilibrium, as velocity is increased, lift must be decreased.

- This is normally accomplished by reducing the AOA by lowering the nose. Conversely, as the aircraft is slowed, the decreasing velocity requires increasing the AOA to maintain lift sufficient to maintain flight.

- There is, of course, a limit to how far the AOA can be increased, if a stall is to be avoided.

✓ THRUST AND DRAG

- Thrust has a definite relationship with drag. These relationships are quite simple, but very important in understanding the aerodynamics of flying.
- Wing area is measured in square feet and includes the part blanked out by the fuselage.
- Wing area is adequately described as the area of the shadow cast by the wing at high noon.
- Tests show that lift and drag forces acting on a wing are roughly proportional to the wing area.
- This means that if the wing area is doubled, all other variables remaining the same, the lift and drag created by the wing is doubled. If the area is tripled, lift and drag are tripled.

- Drag must be overcome for the aircraft to move, and movement is essential to obtain lift.
- To overcome drag and move the aircraft forward, another force is essential. This force is thrust. Thrust is derived from jet propulsion or from a propeller and engine combination.
- Jet propulsion theory is based on Newton's third law of motion. The turbine engine causes a mass of air to be moved backward at high velocity causing a reaction that moves the aircraft forward.
- In a propeller/engine combination, the propeller is actually two or more revolving airfoils mounted on a horizontal shaft.
- The motion of the blades through the air produces lift similar to the lift on the wing, but acts in a horizontal direction, pulling the aircraft forward.

8.3.2 Glide ratio

- ✓The *glide ratio* of an airplane is the distance the airplane will, with power off, travel forward in relation to the altitude it loses.
- ✓ **Glide Ratio** = Horizontal Distance divided by the Change in Altitude.
- ✓ For example, if an airplane travels 10 000 feet forward while descending 1 000 feet, its glide ratio is said to be 10 to 1.
- ✓The glide ratio is affected by all four fundamental forces that act on an airplane (weight, lift, drag, and thrust).

✓Variations in weight do not affect the glide angle provided the pilot uses the correct airspeed.

✓Since it is the Lift Over Drag (L/D) ratio that determines the distance the airplane can glide, weight will not affect the distance.

✓The glide ratio is based only on the relationship of the aerodynamic forces acting on the airplane.

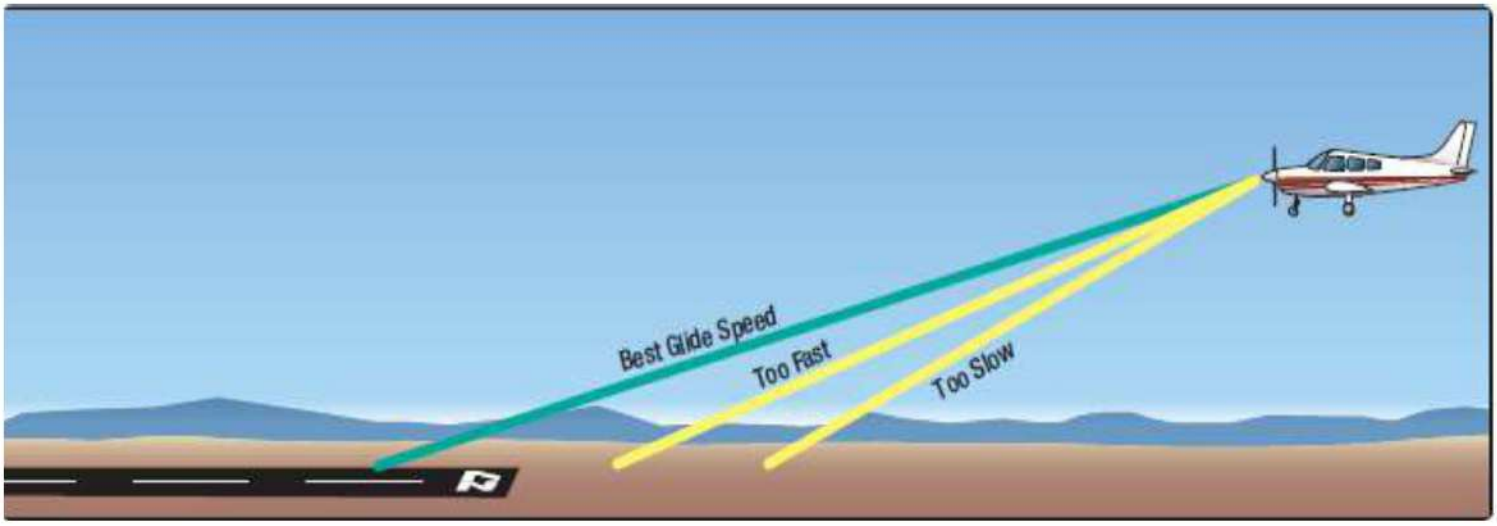
✓ The heavier the airplane the higher the airspeed must be to obtain the same glide ratio.

- ✓For example, if two airplanes having the same L/D ratio, but different weights, start a glide from the same altitude, the heavier airplane gliding at a higher airspeed will arrive at the same touchdown point in a shorter time.

- ✓Both airplanes will cover the same distance, only the lighter airplane will take a longer time.

- ✓Under various flight conditions, the drag factor may change through the operation of the landing gear and/or flaps.

- ✓When the landing gear or the flaps are extended, drag increases and the airspeed will decrease unless the pitch attitude is lowered.
- ✓ As the pitch is lowered, the glide path steepens and reduces the distance traveled.
- ✓Power is not used during a glide or power-off approach, the pitch attitude must be adjusted as necessary to maintain a constant airspeed.
- ✓The best speed for the glide is one at which the airplane will travel the greatest forward distance for a given loss of altitude in still air .
- ✓This best glide speed corresponds to an angle of attack resulting in the least drag on the airplane and giving the best Lift-to-Drag ratio (L/Dmax).



Best glide speed provides the greatest forward distance for a given loss of altitude

- ✓Any change in the gliding airspeed will result in a proportionate change in glide ratio.
- ✓The glide airspeed is reduced or increased from the optimum or best glide speed, the glide ratio is also changed.
- ✓When descending at a speed below the best glide speed, induced drag increases.
- ✓When descending at a speed above best glide speed, parasite drag increases.

8.3.3 Steady State flight

✓ The four forces

- Now, what are the forces which keep the aeroplane in its state of steady level flight?
- First the **lift**, which will be vertically upwards since the direction of motion is horizontal.
- This we have created with the express object of keeping the aeroplane in the air by opposing the force of gravity, namely, the **weight**
- But we can only produce lift if the aeroplane is moved forward and for this need the **thrust** provided by the propeller or jets.
- We also know that the forward motion will be opposed by the **drag**

1. The Lift, *L*, acting vertically upwards through the Centre of Pressure.

2. The Weight of the aeroplane, *W*, acting vertically downwards through the Centre of Gravity.

3. The Thrust of the engine, *T*, pulling horizontally forwards.

4. The Drag, *D*, acting horizontally backwards.