## Why Lift Reserve at stall is 0% and it is 40% at Approach?

The relationship between speed and lift is NOT linear—it's an **inverse-square relationship**.

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Because lift is tied to the square of your velocity, small changes in speed at the slow end of the spectrum (near stall) require massive changes in the Coefficient of Lift ($C_L$) to stay airborne.

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### The "Lift Budget" Breakdown

Think of your aircraft's total lift capacity as a **100% Budget**. To stay in the air, you must spend a certain percentage of that budget, based on how fast you are going.

#### 1. The Inverse-Square Law

In steady, level flight, the relationship between the **Coefficient of Lift ($C_L$)** and **Velocity (V)** is Inverse-Square. Think of them as a "balancing act" used to keep an aircraft in level flight.

### The Balancing Act

For an airplane to maintain a constant altitude, the **Lift** it produces must exactly equal its **Weight**. The formula for lift looks like this:

$$L = (1/2) \times C_L \times \rho \times V^2 \times S$$

In this equation:

- **L** is Lift (which must stay constant to stay level).
- **$C_L$** is the Coefficient of Lift (determined by the wing's shape and its **Angle of Attack**).
- **V** is Velocity (Airspeed).

As $C_L$ and V are on the same side of the equation, they have an **inverse-square relationship**. If one goes up, the other must go down to keep the total Lift the same.

$$C_L \alpha \ 1/V^2$$

This means if you slow down, your $C_L$ must increase significantly to compensate. In other words, as you slow down – reducing velocity; you must pull the nose up significantly more, to stay in the air.

**Real-World Example: The Approach & Landing**

Imagine you are flying a Cessna 172. You are in level flight, but you want to slow down to land.

1. **High Speed (Cruise):**
   - **Velocity (V):** High (e.g., 110 knots).
   - **Coefficient of Lift ($C_L$):** Low.
   - **Pilot Action:** You push the nose down slightly. The wing is very efficient at high speeds, so it only needs a tiny "bite" of air (low Angle of Attack) to generate enough lift to support the plane's weight.

2. **Low Speed (Approach & Landing):**
   - **Velocity (V):** Low (e.g., 55 knots).
   - **Coefficient of Lift ($C_L$):** High.
   - **Pilot Action:** As you slow down, the air hitting the wing has less "energy." To prevent the plane from sinking, you must pull the nose up to increase the Angle of Attack. This increases the $C_L$ to compensate for the loss of V.

**Now comes the "Inverse Square" Factor**

To understand the **inverse-square law**, you just need to imagine how a fixed amount of "stuff" (like light, sound, or gravity) has to spread out as it travels away from its source.

The rule is simple: if you **double** the distance from the source, the intensity doesn't just drop by half—it drops to **one-fourth**. If you **triple** the distance from the source, the intensity drops by **one-ninth.**

For example, the relationship between distance and WiFi signal strength follows the **inverse-square law, (**disregarding obstruction). Doubling your distance from the router doesn't just cut the signal in half—it reduces it to **one-fourth** of its original strength. This explains why moving just a few rooms away can cause such a significant drop in connection quality.

Notice that in the Lift formula, Velocity is **squared** ($V^2$). **This is a big deal for pilots**.

If you cut your speed in **half**, your lift doesn't just drop by half—it drops by **four times**. If you cut your speed to 1/3, your lift drops by 9 times. To stay level at half the speed, your $C_L$ (linearly related to Angle of Attack) has to work four times harder. This is why airplanes have a "Stall Speed"; eventually, you are going so slow that you cannot physically tilt the wing back far enough to create a high enough $C_L$ to match the weight of the plane.

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**2. The 1.30 Rule (The "Approach Margin")**

Aviation standards typically set the Approach Speed ($V_{App}$) at **1.30 times** the Stall Speed ($V_{stall}$). When we plug that into our lift equation, the math reveals why the "safety cushion" feels the way it does.

At Stall, the equation of Lift will be:

$L_{Stall} = (1/2) \times C_{L,Stall} \times \rho \times V_{Stall}^2 \times S$

At Approach, the equation of Lift will be:

$L_{App} = (1/2) \times C_{L,App} \times \rho \times V_{App}^2 \times S$

With the Weight of the airplane remaining unchanged, $L_{Stall}$ and $L_{App}$ are linearly proportional.

So, $L_{App} \; \alpha \; L_{Stall}$

$[(1/2) \times C_{L,App} \times \rho \times V_{App}^2 \times S] \; \alpha \; [(1/2) \times C_{L,Stall} \times \rho \times V_{Stall}^2 \times S]$

$[C_{L,App} / C_{L,Stall}] \; \alpha \; [V_{Stall}^2 / V_{App}^2]$

$[C_{L,App} / C_{L,Stall}] \; \alpha \; [V_{Stall}^2 / (1.30 \times V_{Stall})^2]$

$[C_{L,App} / C_{L,Stall}] \; \alpha \; [1 / (1.3)^2] = 1 / 1.69$ …. (approx 0.60)

$C_{L,App} \; \alpha \; 0.60 \times C_{L,Stall}$

- **At Stall ($V_{stall}$):** You are using **100%** of your available $C_L$. Your "**Lift Reserve**" is **0%**.
- **At Approach (1.3 * $V_{stall}$):** You are using only **~60%** of your available $C_L$. Your **Lift Reserve** is **40%**.