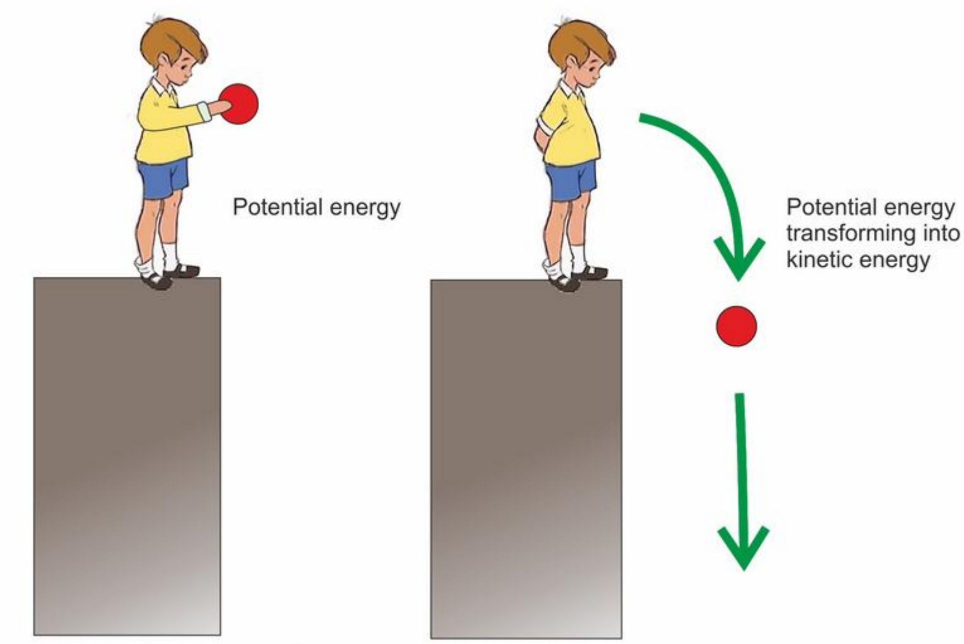
Energy Management

From "*Private, Commercial, Sport Pilot Training Manual*" at RealCFI.com

Reference Airplane Flying Handbook, Chapter 4

Potential Energy= mass of aircraft (kg) x height (m) x acceleration of gravity (9.8m/s/s). Potential energy is also considered "stored" energy, like a ball at the top of a building. Note, during an approach to landing, neither the mass of aircraft nor gravity changes significantly. So, we can consider our height above ground as a relative measure of potential energy. Pilots are pretty good at estimating height with practice.

Kinetic Energy = ½ mass of aircraft (kg) x Velocity^2. Kinetic energy is movement energy, like a ball rolling down a hill or tossed from atop a building. Notice our kinetic energy varies with the square of the velocity. Double our velocity means quadruple our energy! Pilots are terrible at detecting relative speed and then squaring the result.



Total Energy = Kinetic + Potential. Energy is neither created nor destroyed. However, kinetic energy can be converted into potential and vice versa! As the ball rolls down a hill or is dropped from a height, the potential energy is converted to kinetic as the ball speeds up. Conversely as a ball rolls up a hill it slows down as it converts its kinetic energy to height. We can do this same thing with the "Kinetic energy converter" installed in every aircraft – it is called the "Elevator". Pulling back on the yoke will convert our kinetic energy (speed) to potential energy (altitude). Hence the concept of "trading" speed for altitude or trading altitude for speed. The key point here is our energy state doesn't change significantly. An example of this is if we are high on final approach, pitching down lowers our altitude but increases our speed. Our total energy state doesn't change much and consequently will still land at approximately the same place! (note there is some increase in parasitic (speed) drag when we pitch down and some induced (AOA) drag when we pitch up but neither bleed much energy.) *Moral of the story is NEVER dive for the runway if you are high and NEVER "stretch" a glide by pitching up. Neither works. The solution is change in power or drag (flaps, slip).*

Determining Height above runway on Final. Consider two training aircraft of same weight on final. A is traveling at 50 KIAS, B at 70 KIAS. They are both 300 ft above the ground. Both pilots believe they are at proper altitude and energy state to land on their spot. In this example, both have the same potential energy as they have the same weight and height above the ground. However, aircraft B has nearly double the kinetic energy (70^2 =4900 vs 50^2=2500). If we pitch up aircraft B to slow to 50 KIAS, it will climb approximately 113 ft! **Pilot B will land much further down the runway.** The only way to estimate our height above the runway is if we are ON SPEED! See figures 1 and 2.

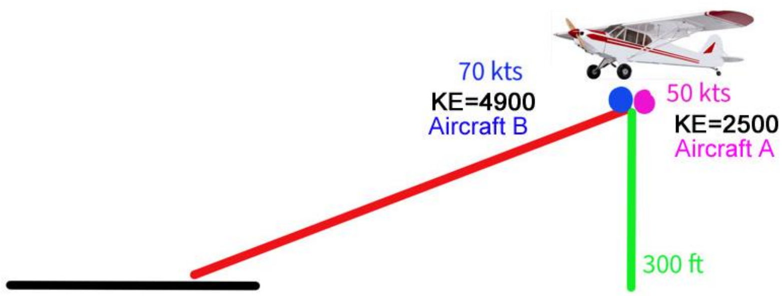


Figure 1. Aircraft A at 300 ft AGL and 50 kts. Aircraft B at same altitude and 70 kts has almost double the kinetic energy assuming same weights.

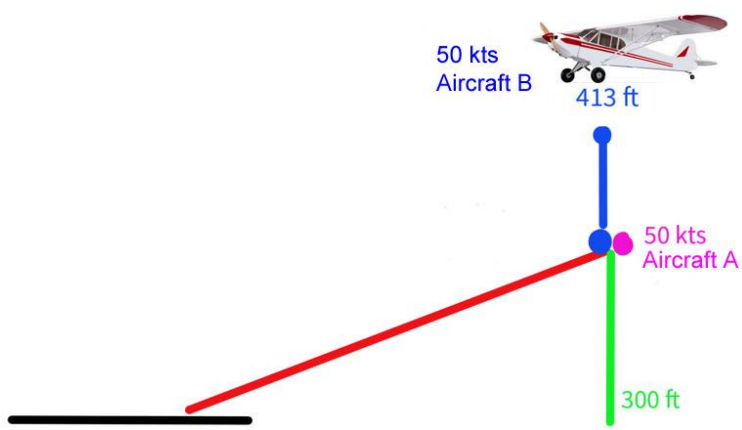


Figure 2. If Aircraft B travelling 70 kts were to use the elevator to reduce speed to 50 kts, it would climb approximately 113 ft (assuming gross weight of 2200 lbs).

Hence, on final approach, I recommend correcting airspeed FIRST with pitch, then adjust descent rate with power. Once the airspeed is corrected and maintained, the pilot only has to control descent rate with power. This method does not preclude simultaneously using both power and pitch if really low or really high. However, in these cases, a go around should be considered as the approach is not stable.

High and fast on the approach. In this case, counterintuitive control inputs are required. Power should be reduced to decrease altitude, simultaneously, the aircraft should be pitched UP to reduce airspeed. Pitching down for altitude does not change the total energy state and only makes the airspeed problem worse. Once airspeed is corrected with pitch, further power changes can be made for the descent rate. If close to the runway or below 500 ft AGL, consider a go around.

Low and Slow on the approach. In this case, the control inputs may seem counter intuitive. The power should be increased to halt the descent, and the aircraft control stick should be pushed forward (pitched down) to gain airspeed. If power is applied simultaneously, the aircraft will not lose altitude. If the aircraft is pitched up prematurely before speed is corrected, the aircraft may approach a stall.

Many pilots are taught to gradually decrease speed from downwind, base, and up to short final, adding the last notch of flaps if needed. If we have continuously changing aircraft speed and configuration during our approach, only reaching Vref on short final, the pilot has little time to change power and pitch to make the landing. In practice, the earlier we slow to Vref, the more time we have to adjust our glide path (with power) to make our accuracy landing.

Stabilized Approach

The Airplane Flying Handbook (AFH) recommends no greater than 1.4 Vso on base and 1.3 Vso on final. Additionally, the AFH defines a stabilized VFR approach as being fully configured and 1.3 Vso no later than 500 ft AGL on a 3^0 glide path (approximately 1.5 miles from runway). This conflicts with the other AFH recommendation that full flaps are applied after final established. My recommendations for a stabilized approach:

- Fly consistent pattern (see lessons rectangular course)
- On Base: No faster than 1.4 Vso
- ½ mile Final and 500 ft AGL
    - Fully configured (no flap or gear changes)
    - 1.3 Vso or slower (Private ± 5 kts, Commercial ± 1 kt)
    - Fully trimmed (hands off to check trim)
- Use no more than ± 300 rpm to adjust descent (at private pilot level)
- Power to idle on round out (10 to 20 ft above runway, level pitch attitude)

Indications for a Go Around: during initial training or at the private pilot level a go around should be initiated if the above criteria are not met. *Landing is the reward for a stabilized approach.* It is safer to execute a go around at 300 ft AGL than a few feet over runway.

Rule of thumb: *In general aviation aircraft, you can reduce approach speed by 1 kt for every 100 lbs below max gross weight. 5 kts excess airspeed increases float by approximately 100 ft.*

Excess speed makes it difficult to judge altitude and perform precision approaches. Additionally, more than 90% of landing accidents are related to excess speed and less than 2% from being too slow. *I recommend no faster than 1.3 Vso, fully configured and trimmed no later than ½ mile final and 500 ft AGL*.

Note on controlling air speed and altitude on final*: Some argue air speed should be controlled with power and altitude with pitch. However, air speed responds slowly to power inputs and changes glide path making precise control difficult. Final approach speed places the aircraft in slow flight and the region of reverse command where pitch controls air speed, and power rate of descent.*

During slow flight, if the aircraft is trimmed and only light pressure applied, when power is applied, the aircraft will pitch up and airspeed will actually decline. If power is maintained, light fore and aft pressures of the control stick will make significant changes in airspeed but altitude will change little. This demonstrates the relative independent control of airspeed and altitude.

If power is used to increase airspeed in slow flight (or on final approach) simultaneous firm forward control pressures are required to keep aircraft from climbing with significant trim change. This results in large changes in energy state which cause a delayed response to airspeed. If using pitch to control descent rate and altitude, simultaneous power changes will still need to be made. Consequently, using power for airspeed is more complex and destabilizing.

It is this author's recommendation to use Pitch for Airspeed and Power for Altitude corrections.