The Four Fundamental Flight Maneuvers: by: Darryl Kalthof www.bayareaflyinglessons.com c2010

Note – you will get even more out of this file if you read a chapter on aerodynamics first!

Elements: Effect and use of the flight controls – know primary and secondary effect of elevator, aileron, and rudder, power and flap use. The "Integrated" or "Composite" method of flight instruction (knowing inside and outside references), looking out 90%of the time. ATTITUDE (mainly Pitch) + POWER = PERFORMANCE
Trim Procedure, light touch on controls, and methods used to overcome over-controlling (let go, don't chase flight instruments.)

EFFECTS AND USE OF THE CONTROLS

The control wheel the pilot holds in his hands is called the Yoke.

Moving the yoke forward and backward controls the elevator, a movable surface at the trailing edge of the horizontal part of the tail:

• Back pressure applied to the elevator control - the airplane's nose rises in relation to the pilot. A secondary effect - more drag.

• Forward elevator pressure - the airplane's nose lowers in relation to the pilot. Secondary effect – less drag.

Turning the yoke left and right controls the ailerons, small surfaces on the outside trailing edges of the wings:

• Right pressure is applied to the aileron control - airplane's right wing lowers, secondary effect – left (adverse) yaw.

• Left pressure is applied to the aileron control, the airplane's left wing lowers, secondary effect – right (adverse) yaw.

Pushing on the bottom of the rudder pedals will control the rudder, a moveable surface at the trailing edge of the vertical tail fin:

• Pressure is applied to the right rudder pedal, the airplane's nose moves (yaws) to the right, secondary effect – right roll.

• Pressure is applied to the left rudder pedal, the airplane's nose moves (yaws) to the left, secondary effect – left roll.

The bottom of the rudder pedals will also turn the nose wheel in the direction of pressure for most planes.

The top of the rudder pedals controls the two main wheel brakes.

Power control: the primary effect of a power change is a change in thrust, a secondary effect is a pitch up when RPM's are increased due to an increase of airflow over the elevator, or pitching down as RPM's are decreased.

Flap control: the primary effect of extending wing flaps is an increase in lift and drag. Secondary effects are a pitching up during flap extension (in the Cessna 172, Piper Warrior, and many other light airplanes) due to the main wings downwash of airflow over the elevator. When flaps are retracted many small planes will pitch down.

How much to move the controls:

The controls will have a natural "live pressure" while in flight and that they will remain in neutral position of their own accord, if the airplane is trimmed properly. With this in mind, the pilot should be cautioned never to think of movement of the controls, but of exerting a force on them against this live pressure or resistance. Movement of the controls should not be emphasized; it is the duration and amount of the force exerted on them that effects the displacement of the control surfaces and maneuvers the airplane.

The amount of force the airflow exerts on a control surface is governed by the airspeed and the degree that the surface is moved out of its neutral or streamlined position. Since the airspeed will not be the same in all maneuvers, the actual amount the control surfaces are moved is of little importance; but it is important that the pilot maneuver the airplane by applying sufficient control ***pressure*** **to obtain a desired result**, regardless of how far the control surfaces are actually moved. The controls should be held lightly, with the fingers, **not grabbed and squeezed**. Pressure should be exerted on the control yoke with the fingers. A common error in beginning pilots is a tendency to “choke the stick.” This tendency should be avoided as it prevents the development of “feel,” which is an important part of aircraft control.

Trim control:

All aircraft have an elevator trim wheel that can be used to relieve the pilot from having to use continuous pressure on the yoke fore or aft. The airplane is designed so that the primary flight controls (rudder, aileron, and elevator) are streamlined with the non-movable airplane surfaces when the airplane is cruising straight-and-level at normal weight and loading. If the airplane is flying out of that basic balanced condition, one or more of the control surfaces is going to have to be held out of its streamlined position by continuous control input. The use of trim tabs relieves the pilot of this requirement. Proper trim technique is a very important and often overlooked basic flying skill. An improperly trimmed airplane requires constant control pressures, **produces pilot tension and fatigue**, **distracts the pilot from scanning, and contributes to abrupt and erratic airplane attitude control.**

A common trim control error is the tendency to Over-control the airplane with trim adjustments. To avoid this the pilot must learn to establish and hold the airplane in the desired attitude using the primary flight controls. The proper attitude should be established with reference to the horizon and then verified by reference to performance indications on the flight instruments. The pilot should then apply trim in the above sequence to relieve whatever hand and avoid using the trim to establish or correct airplane attitude. The airplane attitude must be established and held first, then control pressures trimmed out so that the airplane will maintain the desired attitude in “hands off” flight. Attempting to “fly the airplane with the trim tabs” is a common fault in basic flying technique even among experienced pilots.

Pitch Control:

The main thing to concentrate when looking outside is how much earth you can see over the nose or you aircraft. For example at cruise speed of 110 knots you may be able to see 4 inches of earth from the top of the nose to the horizon line where the earth meets the sky. If you see less you will climb and if you see more you will descend.

Common errors: failure to trim, application of control movements rather than pressures, failure to look outside, un-coordination (not using rudder with aileron inputs, Attempting to establish or correct airplane attitude using flight instruments rather than outside visual reference. Habitually flying with one wing low, over-correcting (when off altitude use a vertical speed 2 times the amount your off altitude).

Straight and Level Flight:

Straight-and-level flight is flight in which a constant heading (+/- 10 deg.) and altitude (+/- 100 feet) are maintained.

Straight flight is accomplished by visually checking the relationship of the airplane's wingtips with the horizon. Both wingtips should be equidistant above or below the horizon (depending on whether the airplane is a high-wing or low-wing type), and the **top of the instrument panel should be level with the horizon**. You can also note a bank on the attitude indicator. Anytime the wings are banked, even though very slightly, the airplane will turn.

In order to notice a slight turn you need to pick out a reference point ahead of the airplane far away on the horizon and ensure that the nose of the airplane continues to point in that direction. You can also note what heading you are on and try to maintain that heading, but looking outside is easier and keeps you scanning for traffic!

Rudder and Ball: In order to find the **neutral point of the ball** on the turn coordinator you need to keep the wings level and use the rudders as required to ensure heading does not change. Once you find the neutral point of the ball you should keep the ball in this position for almost all flight maneuvers to maintain coordination, or nose directly into the relative wind flight.

Level flight is maintained by holding the **proper pitch attitude**. This is obtained by selecting some portion of the airplane's nose as a reference point, and then keeping that point in a fixed position relative to the horizon. You can also check the attitude indicator nose dot to double check the pitch attitude. Your goal is to hold whatever pitch is required for level flight (constant altitude). Once you find the right pitch attitude note amount of earth between the top of the nose and the horizon. You should then trim for hands off flight. You can also adjust the airplane bar on the attitude indicator if required (parallax).

There are 7 different Pitch Attitudes you should memorize **(covers Cessna 152 & 172 and Piper Warrior)**:

	Cruise Descent	Cruise	Pattern	Cruise Climb -for visibility	Takeoff & Landing	Vy –Best Rate	Vx- Best Angle
Inches below or above **Horizon** Line	4-6"	3-4"	2-3"	1"	On Horizon	1-2" above	2-3" above
Airspeed	105 knots	105 knots	85-90 knots	85-90 knots	55 & 45 knots	73-79 knots	59-63 knots
AI pitch	-2 deg.	0 deg.	+2 deg.	+5 deg.	+8 deg.	+9-10 deg	+11-12 deg.
RPM	2100	2400	2100	Full- 2600	Full-tkof, or Idle-1100	Full-2500	Full-2400

Change of airspeed in level flight:

You need to be able to accelerate and decelerate while holding the same altitude. For example you may need to slow down for turbulence or to land. And you will often accelerate after leveling off from a climb. A pilot is able to control the aircrafts thrust and angle of attach.

The amount of lift a wing creates is dependent on its angle of attack and it's airspeed. If your plane weighs 2000 pounds then you want to hold altitude then you will need to always create 2000 pounds of lift. In order to do this at different airspeeds you will need to vary the angle of attack so as to maintain the same lift.

For example when you want to slow down you would reduce power/thrust to about 2000 RPM then increase your angle of attack so your lift does not decrease but remains constant. When you accelerate you will need increase the engine RPM to about 2300 and lower the angle of attack and retrim for hands off flight. Your airspeed will increase until the airplanes thrust and drag are in equilibrium. Your job of trimming the plane will not be over until this happens and the airspeed stops increasing and stabilizes.

Level Turns:

A turn is made by banking the wings in the direction of the desired turn. A specific angle of bank is selected by the pilot, control pressures applied to achieve the desired bank angle, and appropriate control pressures exerted to maintain the desired bank angle once it is established. Altitude: try to maintain +/- 100 feet.

Turn entry:

Be sure to check the aircraft's blind spot is clear before you turn. For a low-wing, just look at your wingtip as you enter the turn. For a high-wing you need to make a coordinated roll in the opposite direction so you can see any traffic that might have been blocked by your wing, then turn in the desired direction.

During a turn entry the following controls are used:

The ailerons bank the wings and so determine the rate of turn at any given airspeed.
The rudder offsets any yaw (mainly adverse yaw from the use of the ailerons.)
The elevator is used to pitch up and increase lift to maintain altitude during the turn. (bank, then yank back)

Power may have to be used to maintain airspeed during the turn by +/- 10 knots.

Shallow turns are those in which the bank (less than approximately 15°) is so shallow that the inherent lateral stability of the airplane is acting to level the wings unless some aileron is applied to maintain the bank.

Medium turns are those resulting from a degree of bank (approximately 20-30°) at which the airplane remains at a constant bank without much pilot effort in smooth air.

Steep turns are those resulting from a degree of bank (35° or more) at which the "over-banking tendency" of an airplane overcomes stability, and the bank increases unless aileron is applied to prevent it.

Adverse Yaw and coordinating rudder use with aileron use:

When applying aileron to bank the airplane, the lowered aileron (on the rising wing) produces a greater drag than the raised aileron (on the lowering wing). This lowered aileron's greater drag yaws the airplane toward the rising wing, or opposite to the direction of turn. To counteract this adverse yawing moment, **rudder pressure must be applied simultaneously with aileron in the desired direction of turn. This action is required to produce a coordinated turn.** If you use a very small amount to yoke pressure to deflect the aileron into the wind very little adverse yaw is generated. If you are very gentile with the ailerons then little to no rudder pressure is need to compensate for adverse yaw. When you wish to roll at a faster rate then you must use more pressure on the ailerons and rudder as well. After the bank has been established in a medium banked turn, all pressure applied to the aileron may be relaxed. The airplane will remain at the selected bank with no further tendency to yaw since there is no longer a deflection of the ailerons. As a result, pressure may also be relaxed on the rudder pedals, and the rudder allowed to streamline itself.

Learning how to use the rudder in a coordinated manner is very hard, but the first step is the use the rudder at all. **You will never get better** at using the rudder until you try to use it for every roll you aircraft make. You will need to use the rudder every time you roll the plane left or right no matter the reason for the roll. You could be rolling in our out of a turn, you might be raising or lower a wing to look for traffic, or you might be fighting some turbulence that is trying to roll the plane away from straight and level flight.

After a few hundred hours of flying time you will be able to feel slightly uncoordinated flight in the "seat of your pants" and by the way you lean to the same side of that airplane as the turn coordinator ball. In the meantime try to use a **proportional amount of rudder** with your aileron inputs and watch the ball to monitor the quality of your turn entries and exits. You should try to be aware of strong or gross un-coordination.

In all constant altitude, constant airspeed turns; it is necessary to increase the angle of attack of the wing when rolling into the turn by applying up, or back elevator. This is required because part of the vertical lift has been diverted to horizontal lift. Thus, the total lift must be increased to compensate for this loss. You can watch the center of the nose position relative to the horizon, and try to keep it constant. You can also try to keep a zero pitch on the attitude indicator. The steeper the bank angle the more backpressure and power you will need to maintain altitude and airspeed.

Also during a steep turn the outside wing travels faster than the inside wing, so it develops more lift. This creates an over-banking tendency that must be controlled by the use of the ailerons a bit of opposite aileron. Because the outboard wing is developing more lift, it also has more induced drag. This causes a slight slip during steep turns that must be corrected by use of the inside rudder.

Turn exit:

To stop the turn, use coordinated aileron and rudder applied in the opposite direction of the turn until wings are level, and release the elevator backpressure. If you did add any power for the turn you will need to return the RPM to the former setting.

Most of the time you will be turning to some outside reference point on the horizon, but you may also be asked to turn to specific heading like 090 degrees. A good rule of thumb is to lead your turn roll out by ½ the degrees is bank. Or 10-15 degrees for a 20-30 degree bank turn.

CLIMBS AND CLIMBING TURNS:

When an airplane enters a climb, it changes its flight-path from level flight to an inclined plane or climb attitude. In a climb, weight no longer acts in a direction perpendicular to the flight-path. It acts in a rearward direction. This causes an increase in total drag requiring an increase in thrust (power) to balance the forces. An airplane can only sustain a climb angle when there is sufficient thrust to offset increased drag created by gravity trying to pull the airplane downhill; therefore, climb is limited by the thrust available.

To enter a climb:

A straight climb is entered by gently increasing pitch attitude to a predetermined level (1” below the horizon, or about 5 degrees pitch in the AI) using back-elevator pressure, and simultaneously increasing engine power to the climb power setting (you need to enrich the mixture, then throttle to full power in fixed pitch prop. aircraft).

Torque and asymmetrical loading of the propeller will cause the airplane to roll and yaw to the left. To counteract this, the right rudder must be used. The slower you fly the stronger these forces are and the less effective the rudder is, so you will have to use more rudder pressure on steeper climbs.

A common error during climbs is to bank right, instead of using right rudder to correct for left turning tendencies.

As the airspeed stabilizes you need to airplane should be re-trim in order to relieve control pressures on the elevator. During the climb if 90 knots give you an inch of visibility over the nose to see and avoid traffic and birds then you should trim for the pitch attitude, the airspeed will normally stay within 5-10 knots of starting speed if you maintain this pitch.

To level off from a climb:

To return to straight-and-level flight from a climb, it is necessary to initiate the level-off at approximately 10 percent of the rate of climb. For example, if the airplane is climbing at 500 feet per minute (f.p.m.), leveling off should start 50 feet below the desired altitude. The nose must be lowered proportionately as the airspeed increases so you reach cruise pitch attitude and airspeed at the same time.

After the airplane is established in level flight at a constant altitude, climb power should be retained temporarily so that the airplane will accelerate to the cruise airspeed more rapidly. When the speed reaches the desired cruise speed, the throttle setting should be set to the cruise power setting (about 2300-2400 RPM), trim the plane and adjust the mixture control as required.

Level off memory aid: pitch and trim, pitch and trim, set power, pitch trim, lean mixture, and read checklist

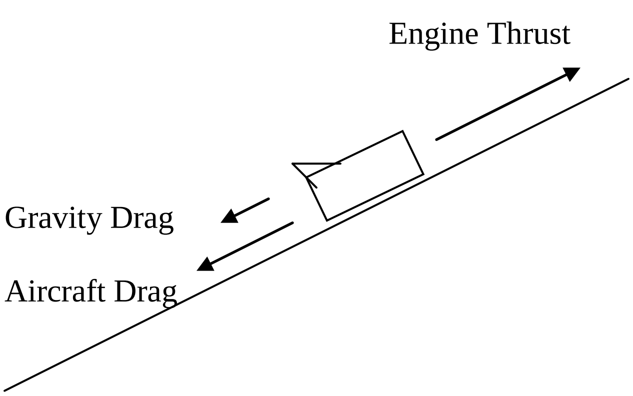
Climbing turns:

To turn while climbing you just need to establish a bank angle in the direction you want to turn. But be sure to look outside to ensure that the center of the nose does not drop during the turn. You can keep it up with increased yoke back pressure, just as you do in the level turns. And remember to relax this backpressure as you exit or roll out of the turn.

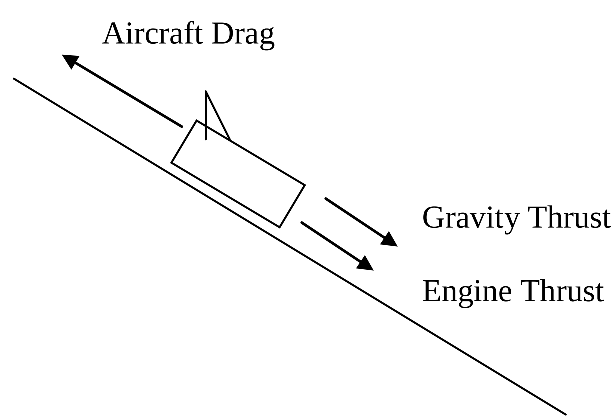
It is harder to stay coordinated during climbing turn entries and rollouts due to the aircrafts slower speed and increased adverse yaw forces. As you enter a climbing right turn you need to use extra right rudder pressure while you roll into your bank, and use less or no right rudder pressure as you roll out of the right turn. Once your bank is established you need to resume normal climbing right rudder pressure.

For the climbing left turn entry just relax your right rudder and let the airplanes left turning forces compensate for the adverse yaw while you roll left into you bank. Again once your bank is established you need to resume normal climbing right rudder pressure. When you exit the climbing left turn you need to use extra right rudder pressure to compensate to the adverse yaw of rolling left.

Climbing Forces:



Descending Forces:



DESCENTS AND DESCENDING TURNS:

Starting a descent:

The easiest descent to make is a cruise descent; where the airplane descends at the same airspeed as it's cruise airspeed. When you descend you are like a car going downhill and gravity will start to pull to plane forward with the affect of increased engine thrust. Because of this all you need to do to start a descent is reduce the power by about 300 RPM and the airplane will lower it's own pitch and "nose over" into a 500 FPM descent while retaining it cruising speed. Most of the time little if any trimming is required to hold the same airspeed.

During a constant airspeed descent you should control airspeed (+/- 10 knots) with your pitch attitude, and use the throttle or RPM setting to control vertical speed (VSI).

Control / Performance method:

If you control the pitch and power setting you will get the performance you desire

FAA's primary and supporting method:

Task	primary pitch	primary bank	primary power
straight and level	altimeter	heading ind.	airspeed ind.
level turn	altimeter	turn coord.	airspeed ind.
climb (constant speed)	airspeed -90	heading ind.	vertical speed
descent (constant speed)	airspeed -110	heading ind.	vertical speed

Note - the attitude indicator (AI) is only primary for pitch or bank changes
- the tachometer (RPM gauge) is only primary during power changes

If you are gliding with idle or zero engine thrust then all you can do is control your airspeed by pitching up or down as required to maintain the desired airspeed.

It is also possible to descend at a higher or lower airspeed then cruise. I call a the first a high speed descent. I try to descend at 500 feet per minute (FPM) while only slightly reducing the RPM so as to not exceed cruise RPM.

A lower than cruise speed descend must be used if you are about to enter the pattern at an airport or you encounter moderate or greater turbulence during your descent. In this case reduce RPM about 500 below the cruise setting and apply yoke backpressure to slow to just below Va or maneuver speed for your current aircraft weight. You can adjust power further as required to establish a 500 FPM descent.

Leveling off from a descent:

To level off you can use the same rule of thumb as a climb: initiate the level-off at approximately 10 percent of the rate of descent. For example, if the airplane is descending at 500 feet per minute (f.p.m.), leveling off should start 50 feet above the desired altitude. You can start this level off by retuning the throttle or RPM to the setting your were using prior to the descent or about 2300-2400 RPM for most planes, and trim as required.

If you have made a large descent of 3000-5000 feet you will have to re-lean the mixture as it might be too lean now as the air is thicker at your new lower altitude.

Descending turns:

To turn while descending you just need to establish a bank angle in the direction you want to turn. But be sure to look outside to ensure that the center of the nose does not drop during the turn. You can keep it at the same pitch attitude with increased yoke back pressure, just as you do in the level turns. And remember to relax this backpressure as you exit or roll out of the turn.