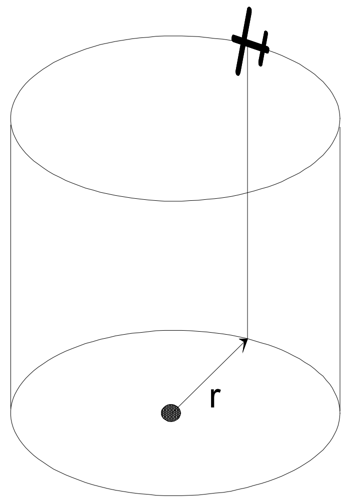
**Turns "about" and "on" a point**

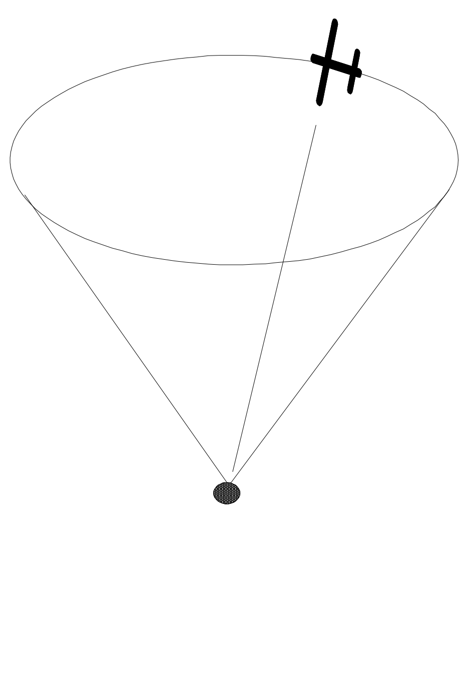
---

Turns and eight's "around" a pylon(reference point on the ground) are designed to be circular tracks, with respect to the reference pylon. Turns and eight's "on" pylons are designed to be at a constant pivotal position with respect to the pylon. Under zero wind conditions both turns *could* be the same. The figure below shows a turn "around" a pylon.




In this turn the projected track of the aircraft is a perfect circle of radius **r** about the reference point. This will hold true regardless of the wind effect on the ground track. In order to fly this pattern the pilot must alter the *bank angle* to maintain the desired *ground track*. The altitude is determined arbitrarily, but should be held constant in this turn.

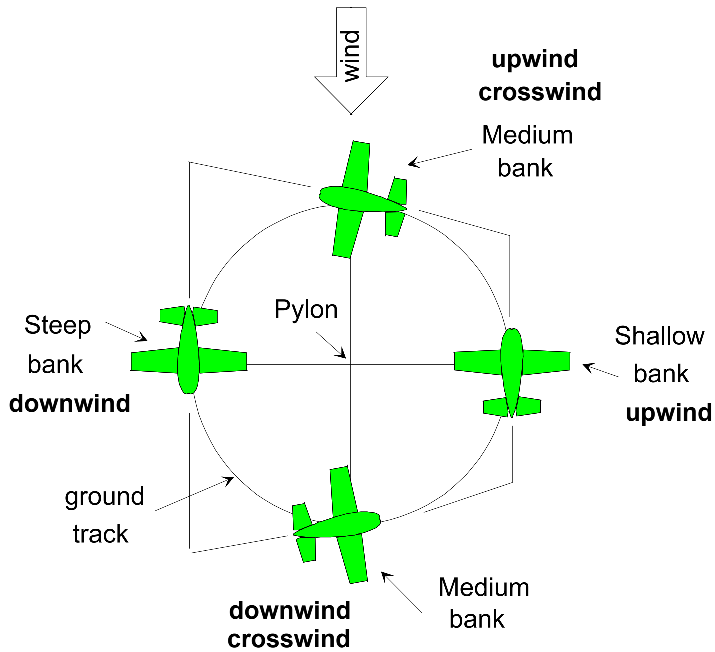
The figure below depicts a turn "on" a pylon.



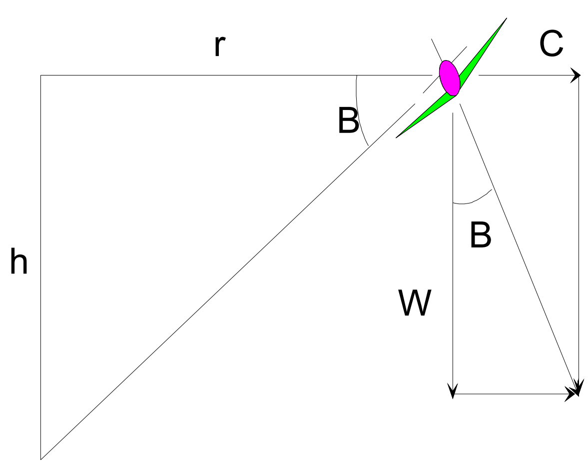
In this turn, the extension of the aircraft lateral axis appears to pivot on the reference point. To fly this turn the pilot must maintain an *altitude and bank angle* that keeps the *pivot point on the pylon*.

**<u>TURNS AROUND A POINT</u>**

The figure below is a projection on the aircraft on the ground track when executing this turn.




In this turn the circular ground track is maintained by varying the bank angle. The turn can be broken down into four basic positions and four segments.  The upwind position must use a relatively shallow bank due the reduced ground speed.  Whereas, the opposing downwind position requires a steep bank to hold the ground track due the effect of the tailwind.  In both cross wind positions the aircraft heading must be turned into the wind so that the instantaneous ground track is tangential to the circular track. The dynamics of an aircraft in a *co-ordinated* turn are shown in the figure below:




Where: **r** = Turn radius

**h** = pivotal altitude
**B** = Bank angle
**W** = weight of aircraft
**C** = centrifical force
**g** = acceleration of gravity
**V** = aircraft linear velocity

The pseudo force C is given by:

$$C = MV^2/r \quad \text{or} \quad C = WV^2/gr$$

**C** can also be found by:

$$C = \tan(B)W$$

Then:

$$V^2 = gr\tan(B)$$

a.) $$r = V^2/g\tan(B)$$

In the case of turns "around" a point **r** and **V** will both be fixed and a.) becomes:

b.) $$B = \tan^{-1}(V^2)/gr$$

**V** is actually the ground speed(speed relative to the pylon). If, for example, an aircraft ant 110 kts airspeed in a wind of 10 kts makes a constant 0.2 nm radius (1215 ft) about a pylon the bank angle at various speeds would be:

| *Turn Radius (ft)* | 1200 | |
|---|---|---|
| **V (kts)** | **Bank Angle** | **G force** |
| 90 | 31 | 1.16 |
| 100 | 36 | 1.24 |
| 110 | 42 | 1.34 |
| 120 | 47 | 1.46 |
| 150 | 59 | 1.94 |
| 175 | 66 | 2.47 |

The bank angle for a turn "around" a point is dependent only on the ground speed(actually, the square of the ground speed) and the turn radius. When the radius is fixed only the *ground speed will determine the required bank angle*.

**<u>TURNS ON A POINT</u>**

The analysis of this turn relies of the same vector diagram as for the turn "about" a point. Eq a.) gives the radius in terms of the bank angle and ground speed. The pivotal altitude is given by:

c.) $$h = r\tan(B)$$

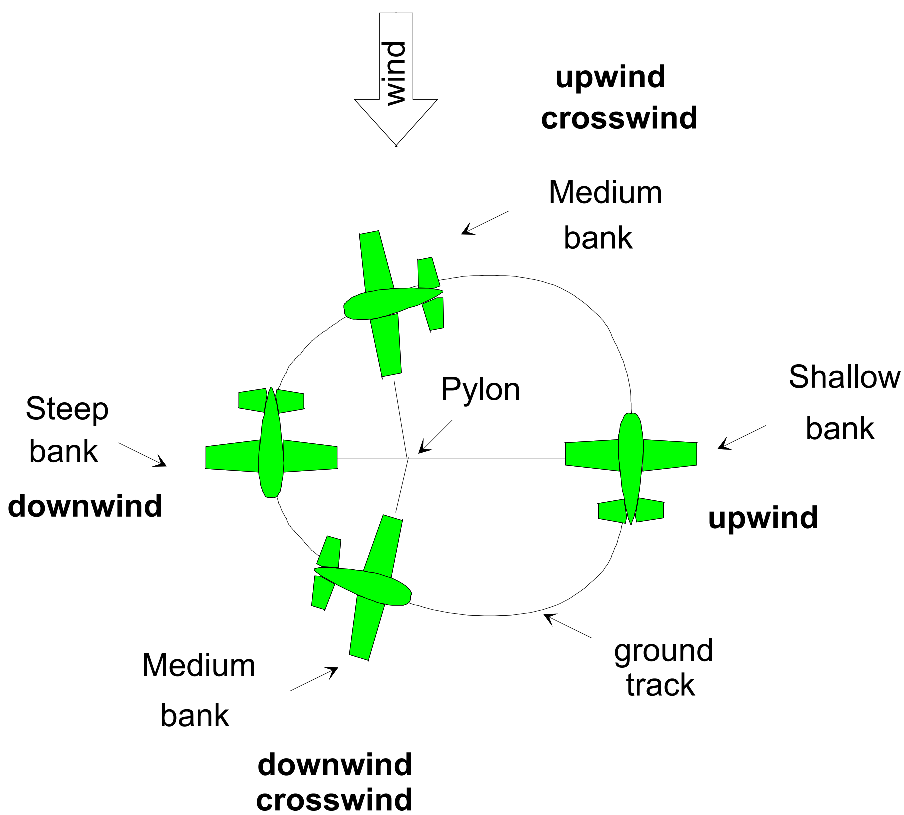
Combining a.) and c.) we get:

d.) $$h = V^2/g$$

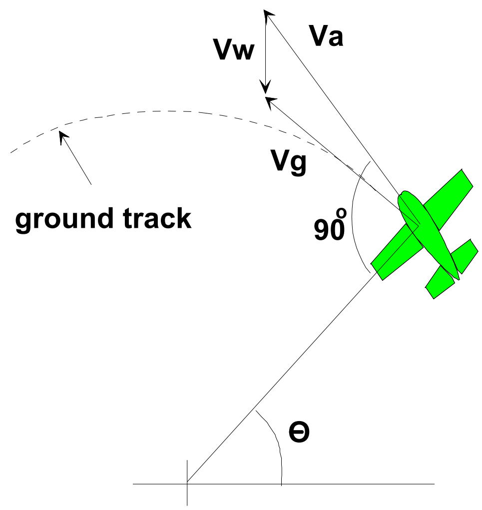
This means that the *pivotal altitude is only dependent on the ground speed*. Several example pivotal altitudes are listed below:

| V (kts) | Pivital Alittude (ft) |
|---:|---:|
| 90 | 716 |
| 100 | 884 |
| 110 | 1070 |
| 120 | 1273 |
| 150 | 1990 |
| 175 | 2708 |

As the aircraft progresses around the turn in a prevailing wind it must climb(with a tail wind) and descend(with a head wind) to maintain pivotal altitude with respect to the pylon. This is only part of the problem of maintaining the pivot point *on* the pylon. The pilot looks along the lateral axis to view the pylon. In order to keep the pivot point on the pylon the lateral axis must always align with the pylon. This precludes heading adjustments to compensate for wind drift. Therefore, this turn will not be circular. Looking at the ground projection of this turn you see the you see figure below:




In the turn "On a Point" the track is egg shaped. The down wind position is nearest the pylon and at the greatest altitude(highest ground speed). This insures that at this position the steepest bank is required. Conversely at the upwind position the lowest ground speed corresponds with the lowest altitude and the shallowest bank. At all positions the airspeed vector is perpendicular to the radius to the pylon. The figure below is the basis for deriving the ground path around the pylon.




Using the example from the turn around a point and equation d.) we can solve for the altitude above the reference point. The radius at each position is fuction of the wind and air speeds.

The ground speed can be expressed as the vector sum of **Vx** and where:

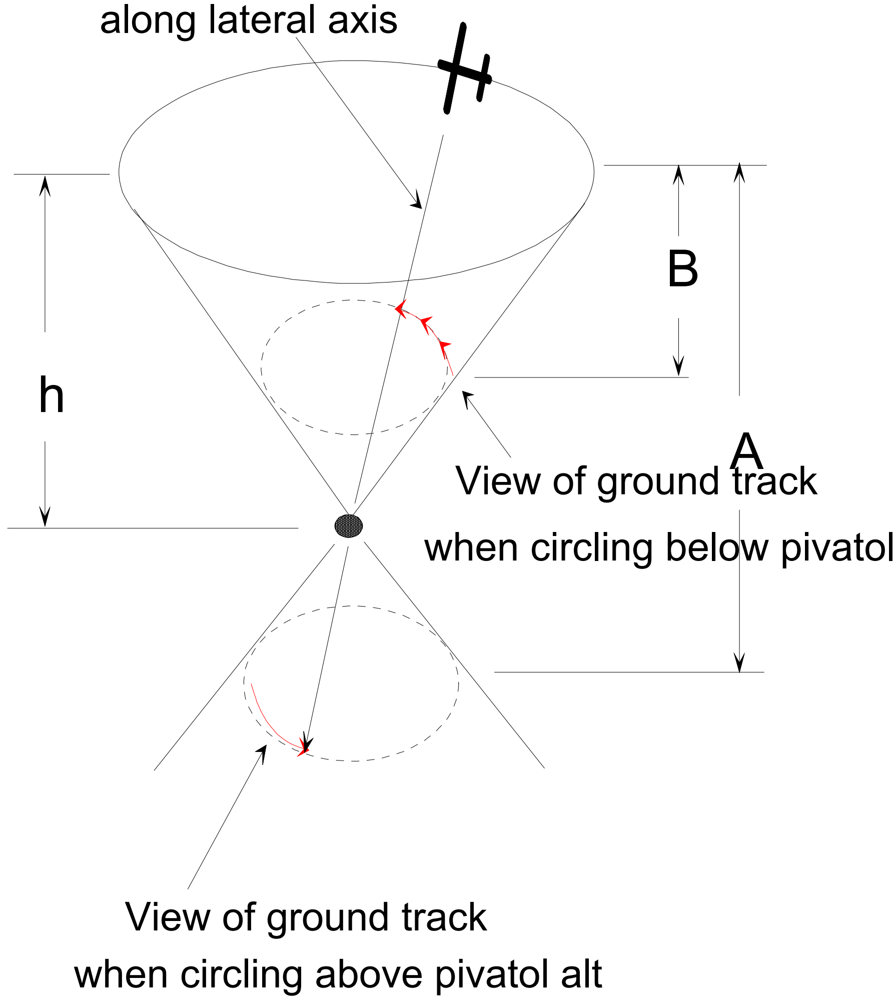
$$\mathbf{Vx = Va[cos(\Theta+\Pi/2)]}$$
$$\mathbf{Vy = Va[sin(\Theta+\Pi/2))] - Vy}$$

and:

$$\mathbf{rd\Theta/dt = iVa[cos(\Theta+\Pi/2)] + jVa[sin(\Theta+\Pi/2)] - Vy}$$

| **position** | **Vground(kts)** | **Pivotal Alt Radius (ft)** |
|---|---|---|
| upwind | 100 | 890 |
| upwind cross wind | 108 | 1036 |
| downwind | 120 | 1280 |
| downwind cross wind | 108 | 1036 |

One more view of the perspective of pivatol altitude is helpful. When the aircraft is circling above the current pivatol altitude the track seen along the lateral axis will seem to move backwards with respect to ground objects. Conversely, when circling below the pivatol altitude the apparent trace of the lateral axis over the ground will move with the aircraft. The figure below shows these viewpoints.




In this sketch the true pivatol altitude is **h** the arrows trace the pilots view of the lateral axis track when circling above, **A**, and below, **B**, the pivatol altitude. Using this as a guide the pilot flies this turn by keeping the pylon frozen on his line of sight along the lateral axis, climbing to move back to the pylon and descending to move forwared to meet the pylon. In addition, he must increase the bank as he climbs to keep the line of sight on the pylon an reduce the bank as he descends.

**SUMMARY**

Both of these turn maneuvers are used to sharpen the pilots skills in flying co-ordinated, maintaining a desired ground track, while keeping an eye out for traffic. The turn "about" a point, being a simple circles over the ground, is the simplest to fly and is used in *private flight* tests. The turn "around" a point is a more complex maneauver and is reserved for the *commercial flight* test. The turns in the commercial ride are applied to "eights" not just simple turns. In the commercial maneauvers the turns are partical turns connected with tangential straigt lines.