DSC Pilot Lectures - Flight Theory

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BHPA Pilot Exam

- Flight Theory
- Meteorology
- Airlaw
- Instruments (and a final run through everything)
- The exam!

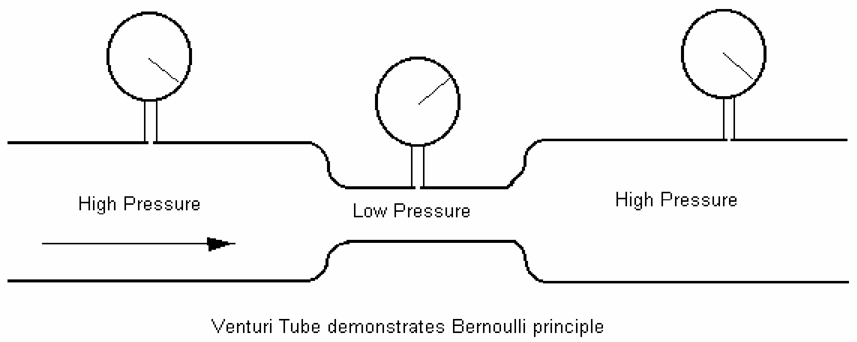
Flight Theory Syllabus

- Explain how a wing creates lift
- Understand aircraft stability
- Forces on a glider
- Understand glide angle and L/D
- Describe the different types of drag
- Describe the aerodynamics of the stall
- Use polar curves
- Understand the effect of ballast
- Understand aeronautical terms

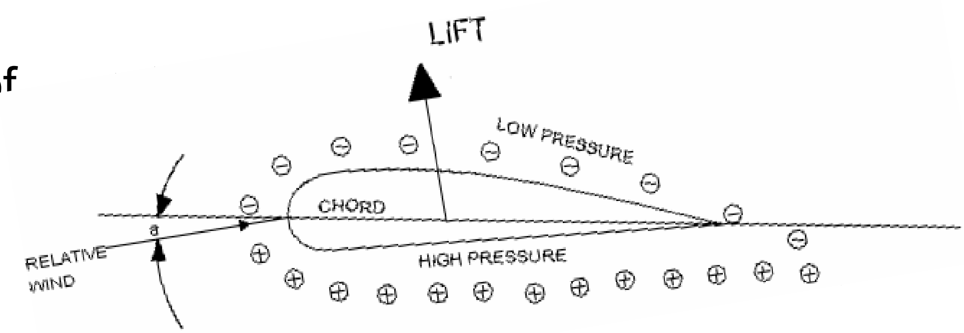
Lift

- Bernoulli effect - air travelling faster over top surface means less pressure on top surface.
- 2/3rd's lift from top surface and 1/3rd from bottom surface
- Lift is a force perpendicular to the airflow hitting the wing.
- Angle of attack is the angle between the airfoil chord and the direction of undisturbed air in front of the wing.
- Drag is the constant penalty of lift

The venturi and Bernoulli effect

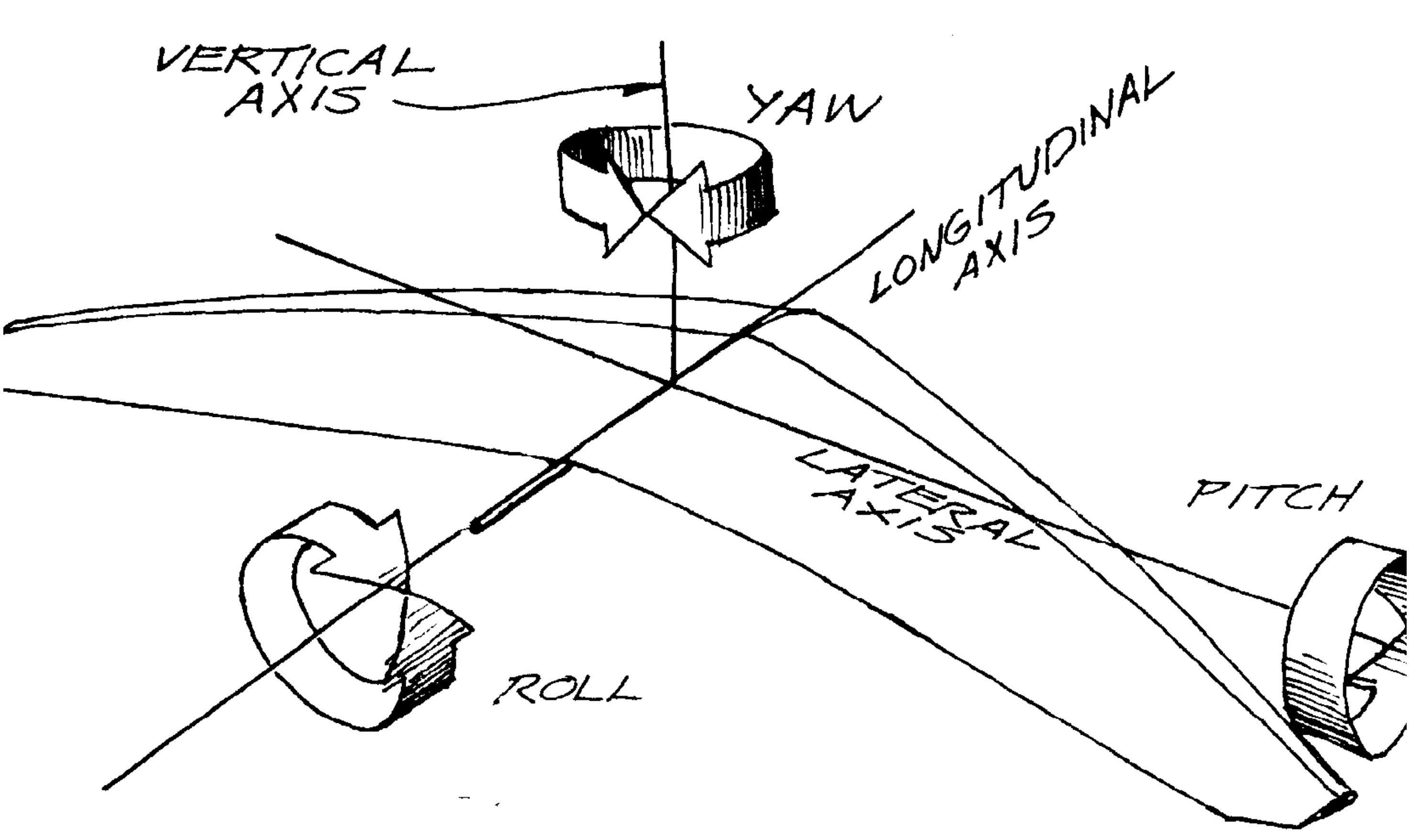


Pressure differences on a wing



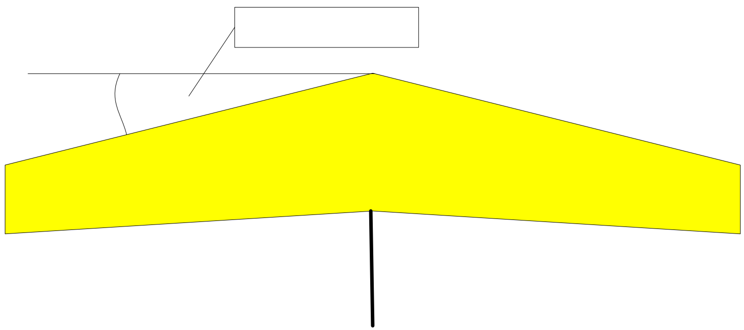
Stability

Stability is a tendency for a glider to return to normal level of flight after disturbance.
Neutral - A glider is given a nudge and it stays where it is
Stable - A glider is given a nudge and it returns to its trim point
Unstable - A glider is given a nudge and it gets even worse.



Pitch Stability

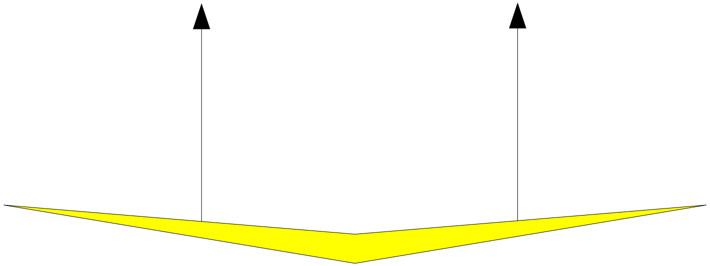
- Sweepback (or just sweep) and washout help glider stability during a stall.
- Washout is a twist in the wing from root to tip and means that the tips are flying at a lower angle of attack than the root.
- Washin is a twist in the opposite direction and the tips fly at a higher angle of attack.
- Hang gliders have **Washout.**
- As the speed slows, the overall angle of attack increases until the stall point. BUT the tips have a lower angle of attack that the root so will still be flying when the root stalls. This cause the centre of pressure to move back and dip the nose and regain flying speed.
- At diving speed, wing **reflex** (luff lines) and tip struts hold the back of the wing up to provide a force to bring the nose back up



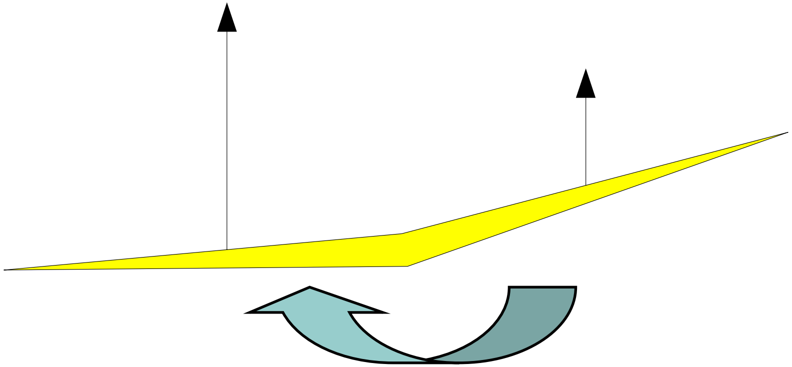
Washout = lower AOA at tips than root

Paraglider pitch stability comes mainly from the pendulum effect and airfoil shape.
Paragliders can have washin (increase in the angle of attack) which firms up the tips in flight

Roll stability

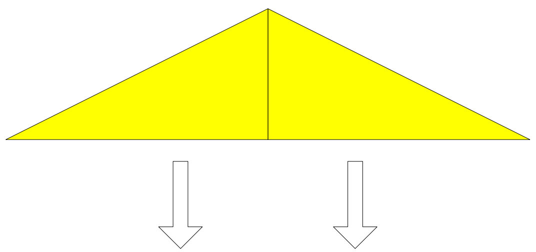


Trim position, each half of the wing produces the same amount of lift

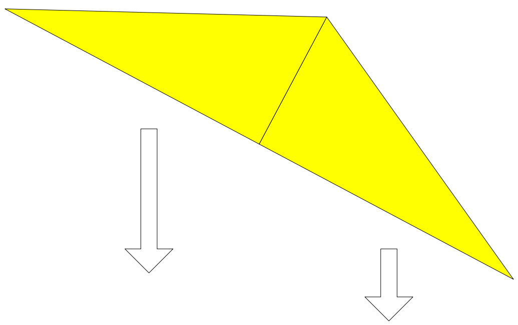


Roll stability due to dihedral in the wing. As the wing rolls, the lower wing produces more lift which acts as a restoring force to the neutral position

Yaw stability



Yaw stability due to sweepback of the wing. Each half of the wing presents the same amount of drag when the wing is trimmed.



If the wing yaws to starboard, the port wing offers more frontal area and therefore more drag than the starboard wing and the overall force is a restoring force to the trim position

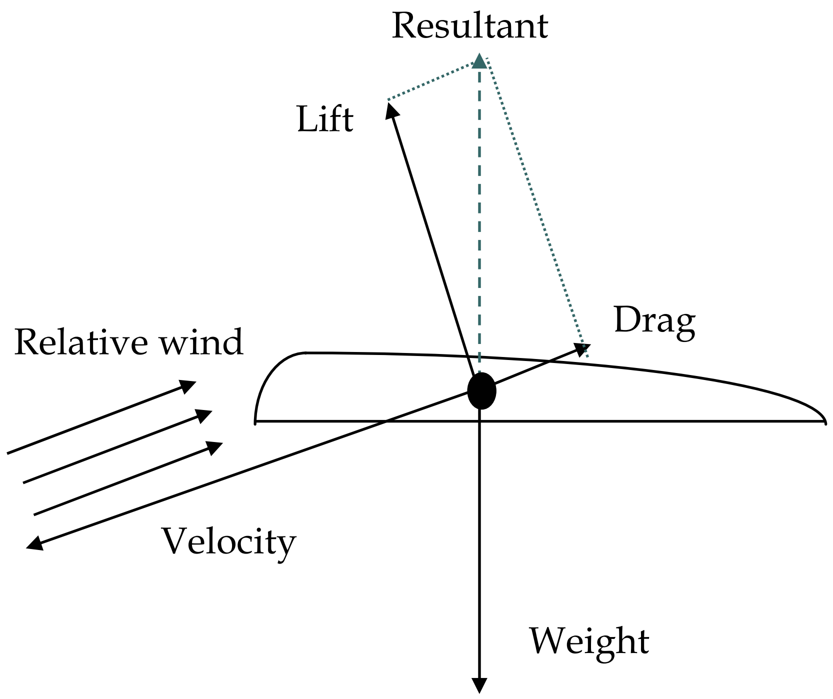
Stability

- Hang gliders
  - Pitch stability from;
    - Reflex
    - Sweepback
    - Washout
    - Airfoil shape
  - Roll stability from;
    - Dihedral
  - Yaw stability from;
    - Sweepback

- Paragliders
  - In the main, the bulk of the stability comes from the pendulum effect.
  - Airfoil shape important in pitch stability

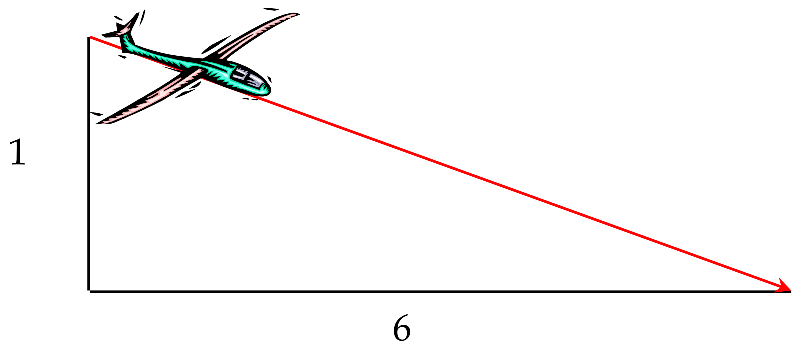
Forces on a glider

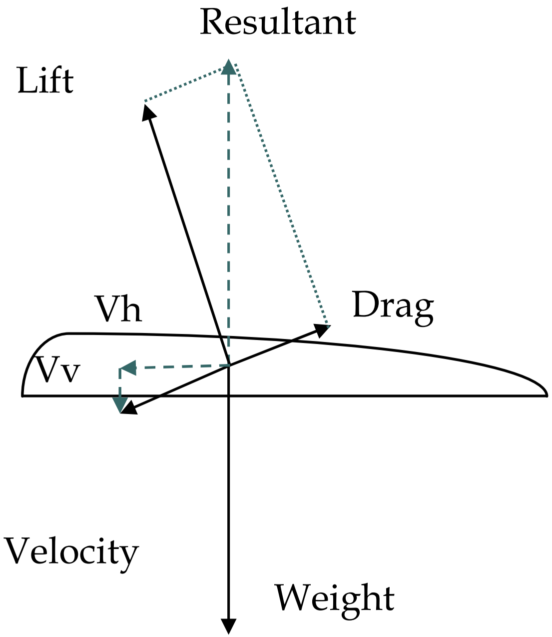
- Lift is perpendicular to the velocity vector which in turn is opposite to the relative wind
- Drag is opposite to the velocity vector
- Lift and drag combine to give the resultant which is equal and opposite to the weight
- Resultant always acts through Centre of Pressure
- Weight always acts through Centre of Gravity
- Above true for steady flight conditions



Glide angle and L/D

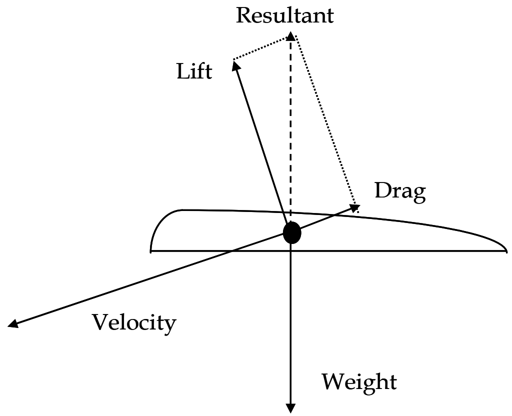
- Glide angle is angle between horizontal and glide slope.
- Sometimes expressed as a ratio of horizontal distance travelled to vertical distance fallen



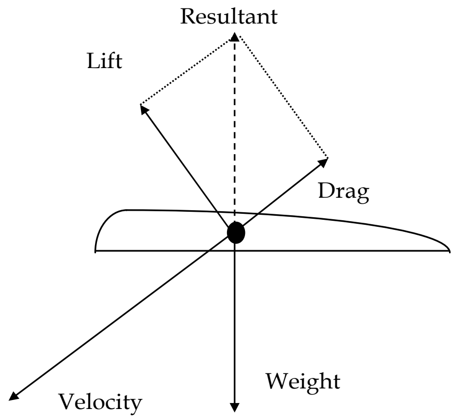


Glide ratio = Vh/Vv = L/D

Forces on a glider



Weight = 120kgs
Resultant = 120kgs
Glide angle = 8:1 (best glide) = L/D = 8/1
Drag = 14.8kgs and lift = 119kgs

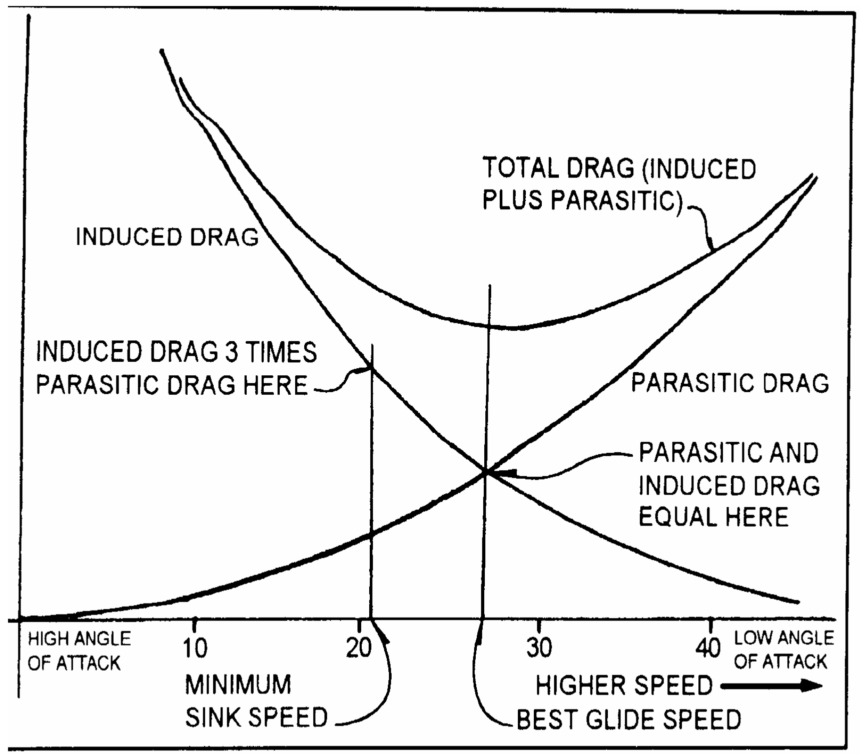


Weight = 120kgs
Resultant = 120kgs
Glide angle = 5:1 (plummetting!) = L/D = 5/1
Drag = 23kgs and lift = 117kgs

Note : Glide angle of 1:1 drag and lift are the same

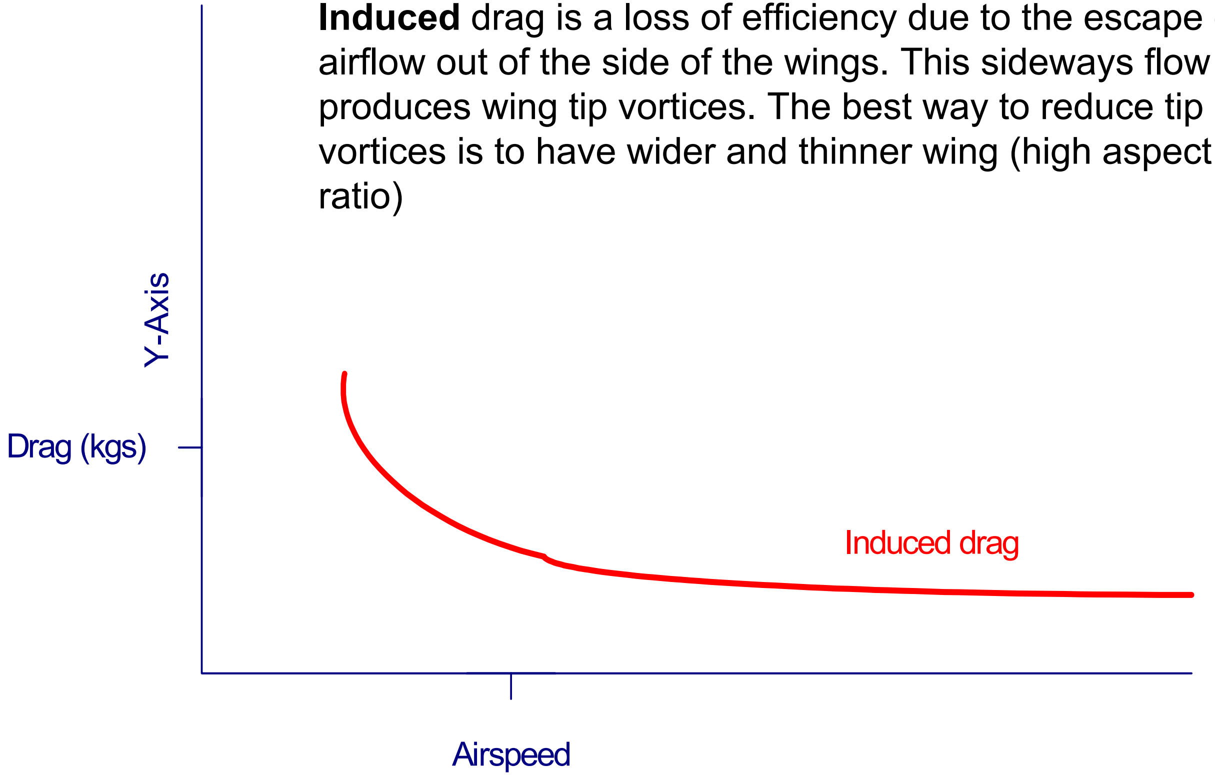
Drag

- Total drag consists of 2 parts, parasitic drag and induced drag;
  - Parasitic drag increases with square of velocity
  - Induced drag represents loss of energy related to producing lift and essentially contained in wing tip vortices. These are greatest at high angles of attack thus induced drag greatest at lower speeds.
- Lowest total drag is best glide



Drag

Induced drag is a loss of efficiency due to the escape of airflow out of the side of the wings. This sideways flow produces wing tip vortices. The best way to reduce tip vortices is to have wider and thinner wing (high aspect ratio)



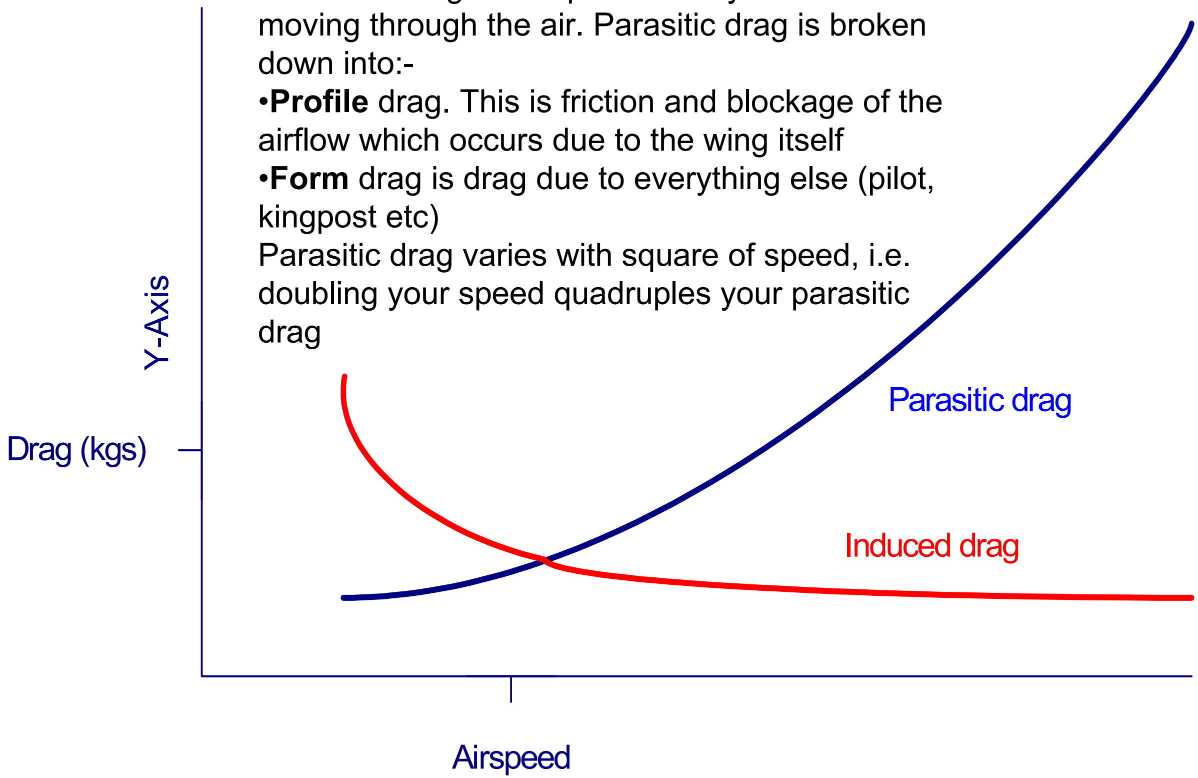
Drag

Parasitic drag is that produced by solid forms moving through the air. Parasitic drag is broken down into:-

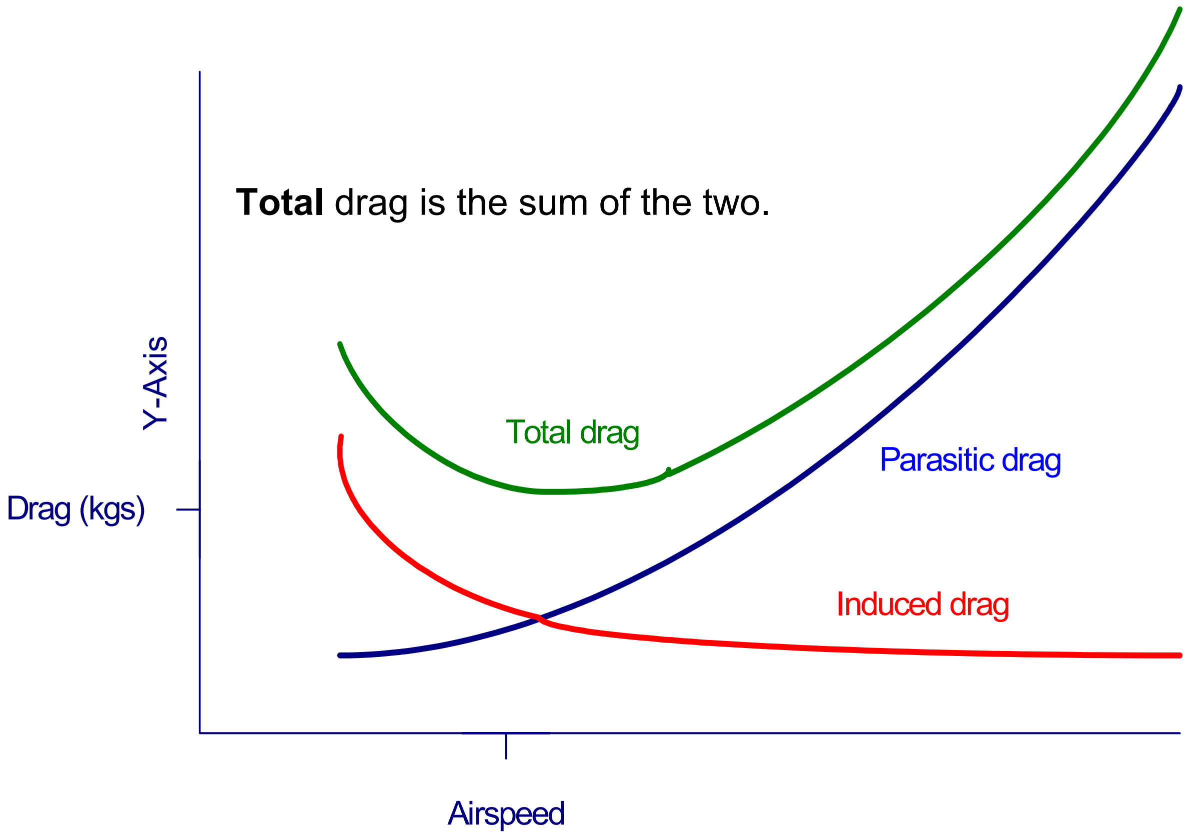
•**Profile** drag. This is friction and blockage of the airflow which occurs due to the wing itself

•**Form** drag is drag due to everything else (pilot, kingpost etc)

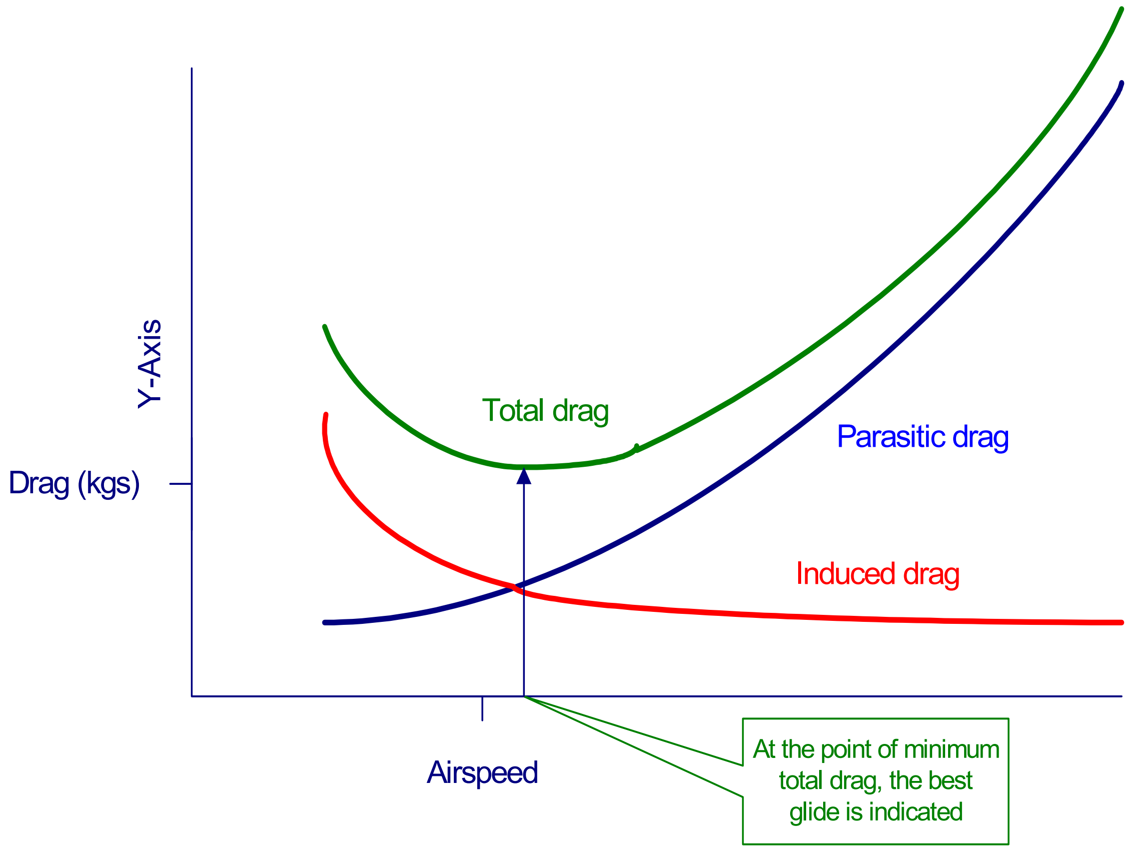
Parasitic drag varies with square of speed, i.e. doubling your speed quadruples your parasitic drag



Drag


Total drag is the sum of the two.
Y-Axis
Drag (kgs)
Total drag
Parasitic drag
Induced drag
Airspeed

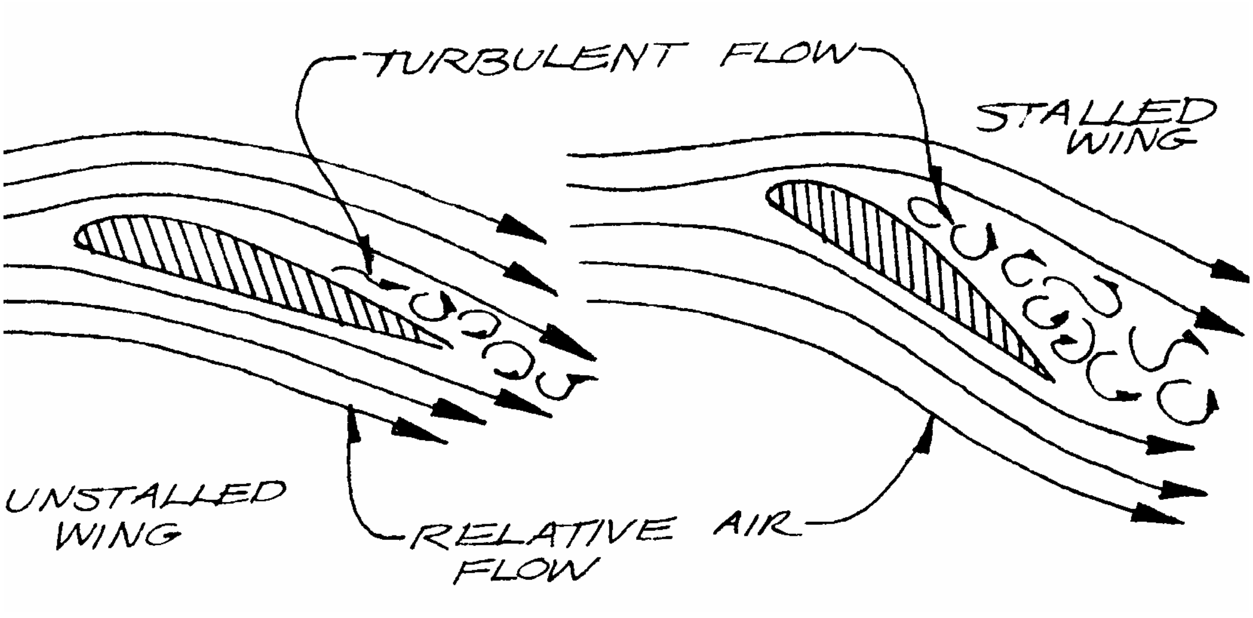
Drag



Y-Axis
Drag (kgs)
Total drag
Parasitic drag
Induced drag
Airspeed
At the point of minimum total drag, the best glide is indicated

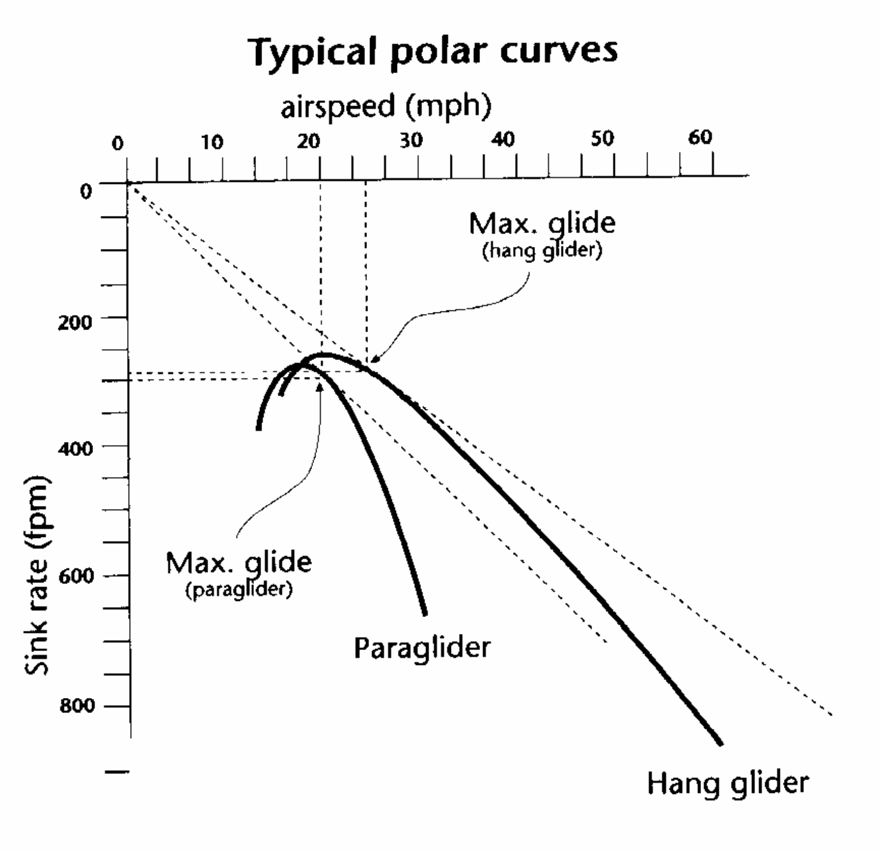
Stall

- Caused by excessive angle of attack
- Increase the Angle of Attack to the stall point and beyond this there is a sudden loss of lift and increase in drag
- Airflow breaks up on the top surface of the glider. Smooth flow is lost.



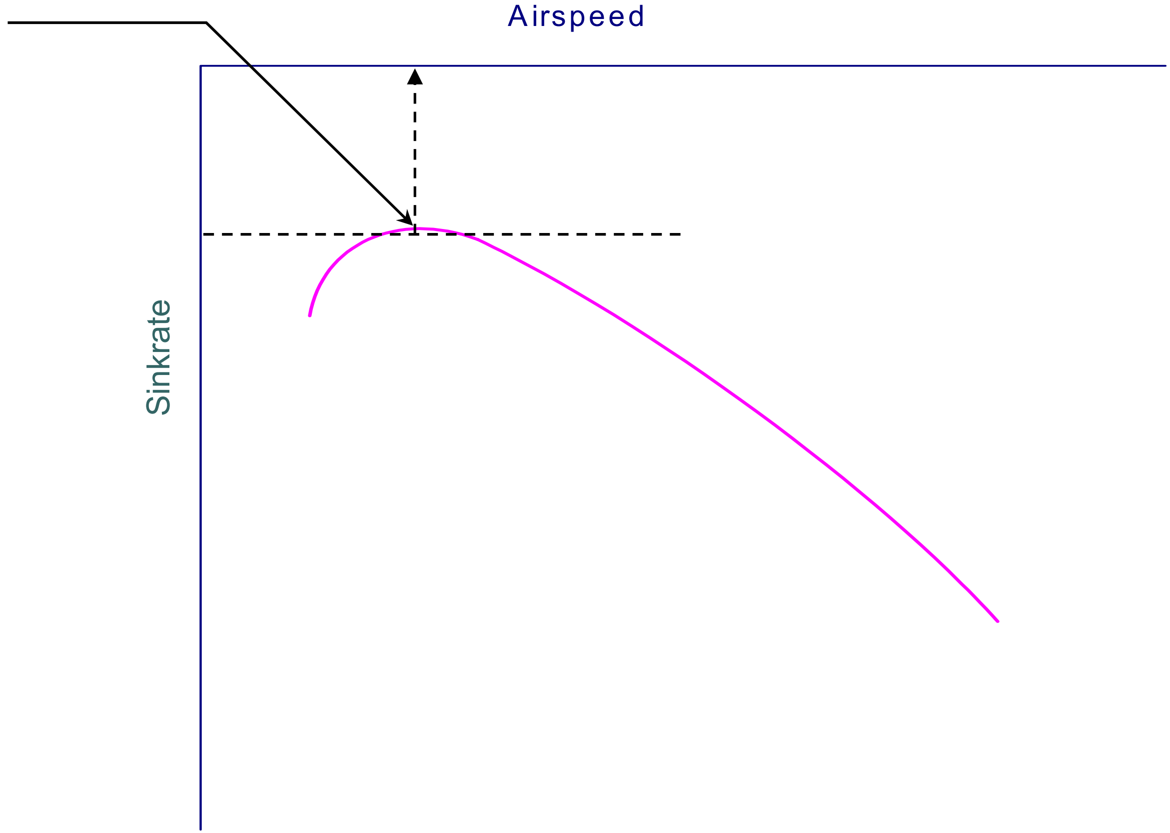
Polar Curves

- Polar curves show airspeed against sink rate.
- For a glider they all have the characteristic shape on the right.
  - Min sink shown by highest point on graph
  - Stall speed shown
  - Best glide obtained by drawing tangent to graph from the necessary point on the axes

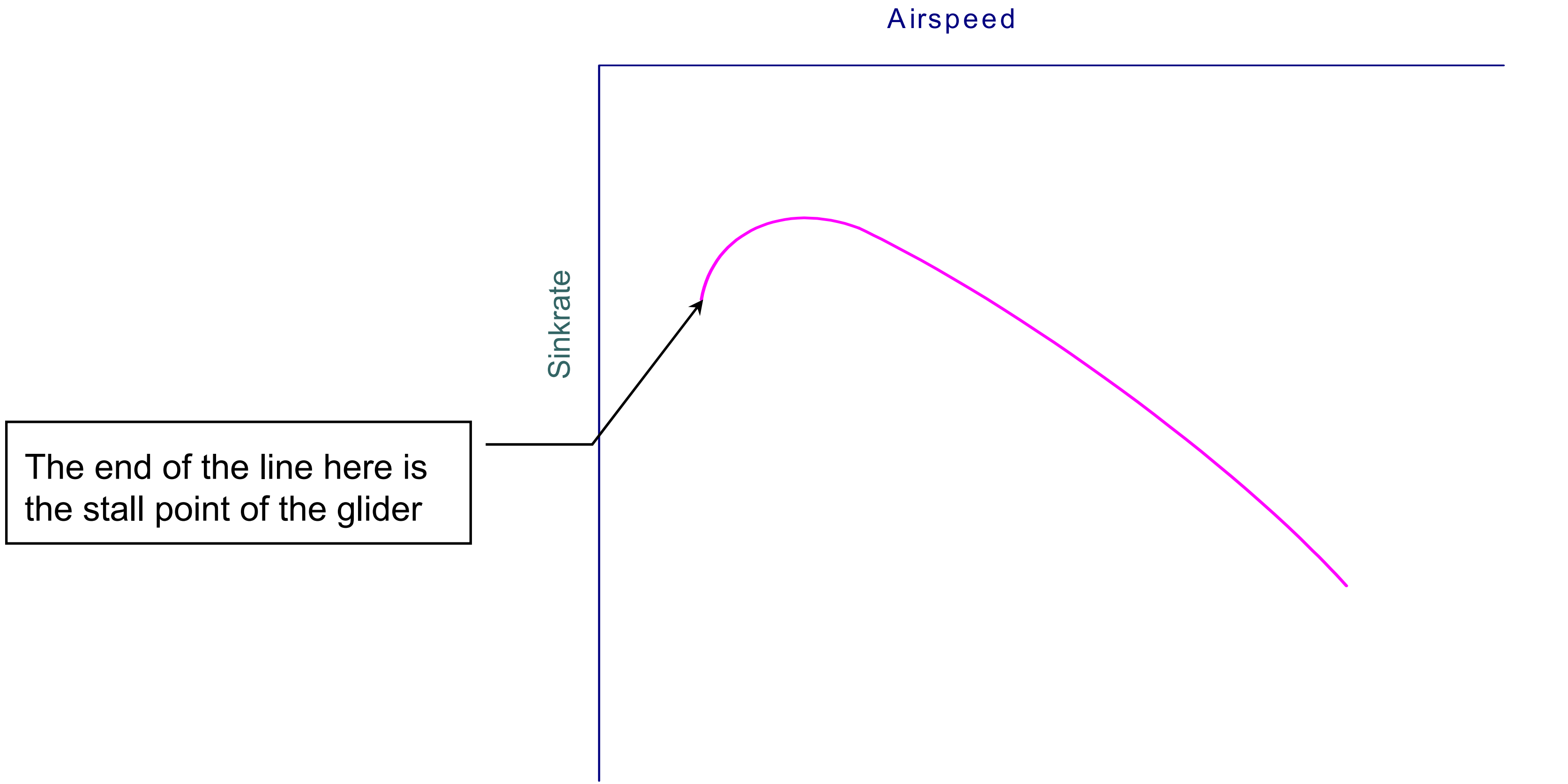


Polar Curves

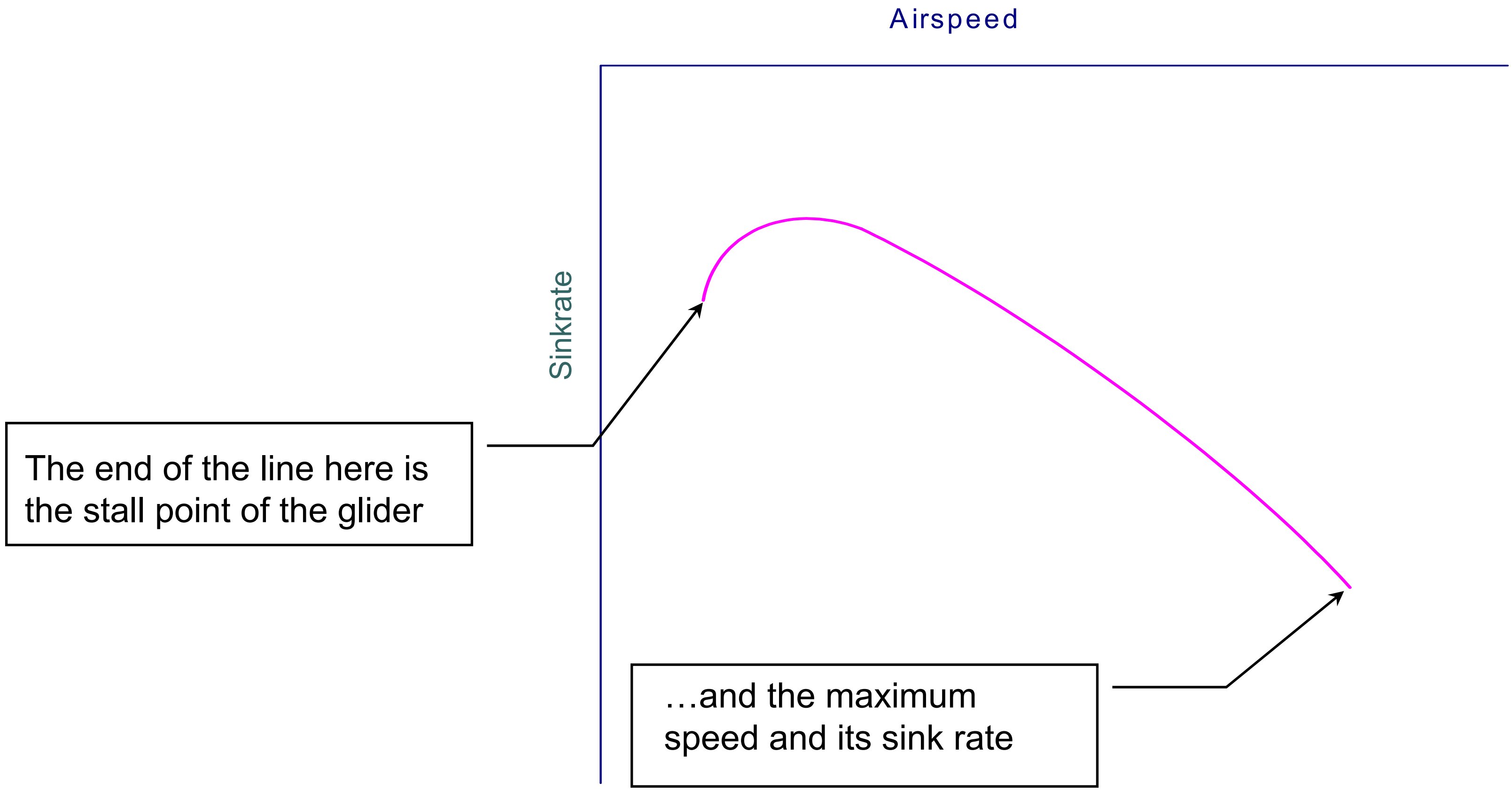
The top of the curve when projected to the airspeed line gives the speed for minimum sink



Polar Curves



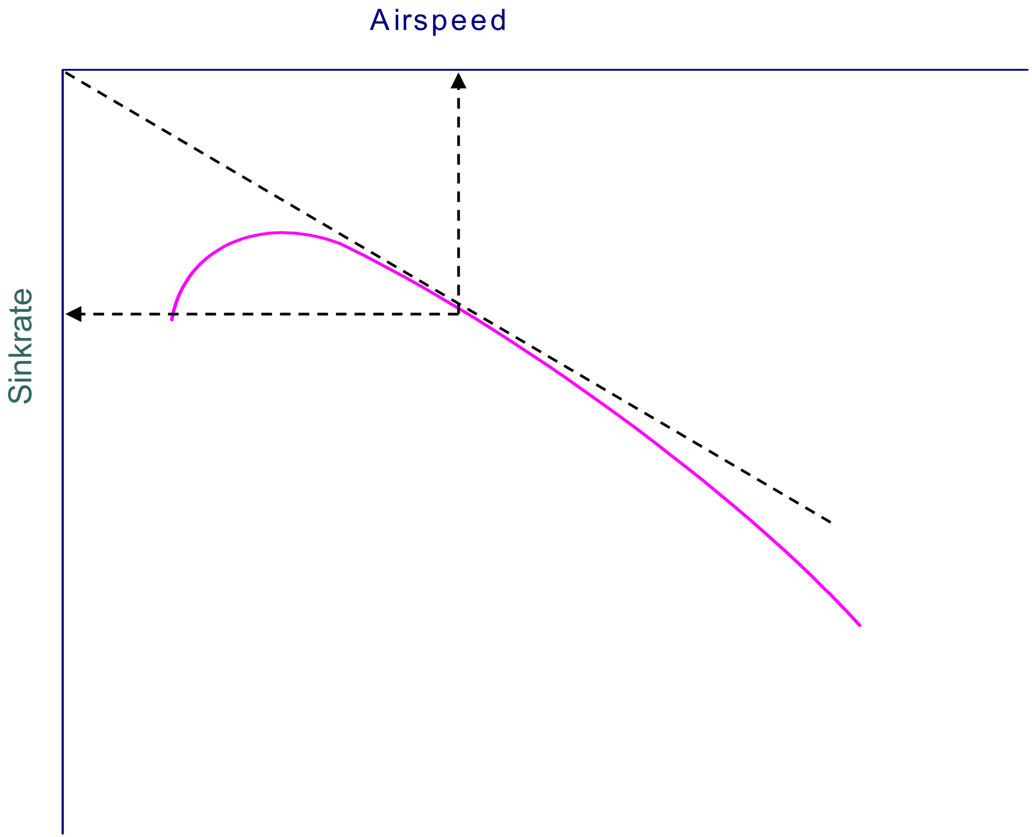
Polar Curves



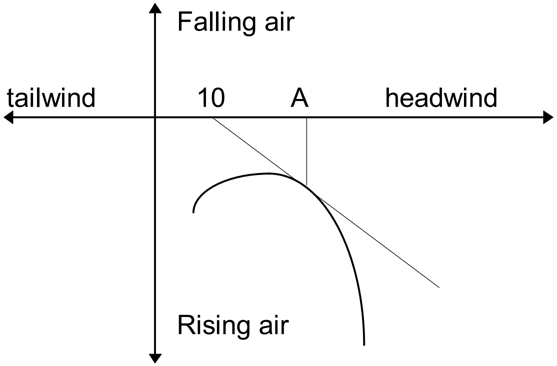
Polar Curves

Draw a line from the origin to the tangent of the curve, then extend this to the x and y axes and you have best glide sinkrate and best glide airspeed.

This only applies in still air

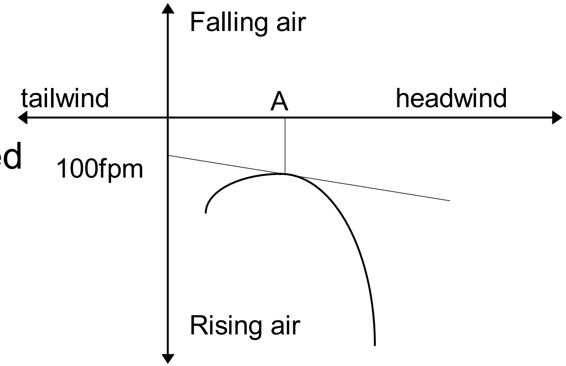


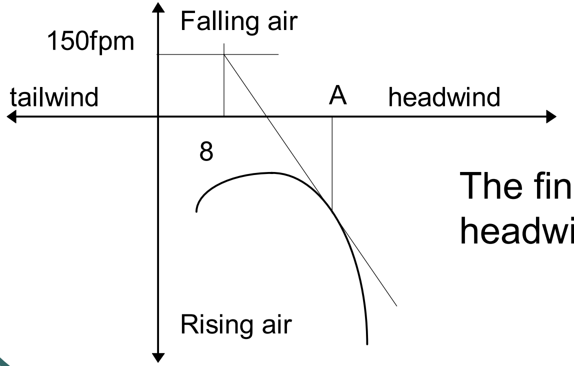
Polar Curves



If we want to find out the speed to fly at in say a head wind of say 10mph. Instead of taking our tangent line from the origin, we take it from the 10mph point on the headwind side of the line. The tangent touches the polar at a faster speed which can be read off at point A. Similarly if we are flying in a tailwind, the polar will tell us to fly slower.

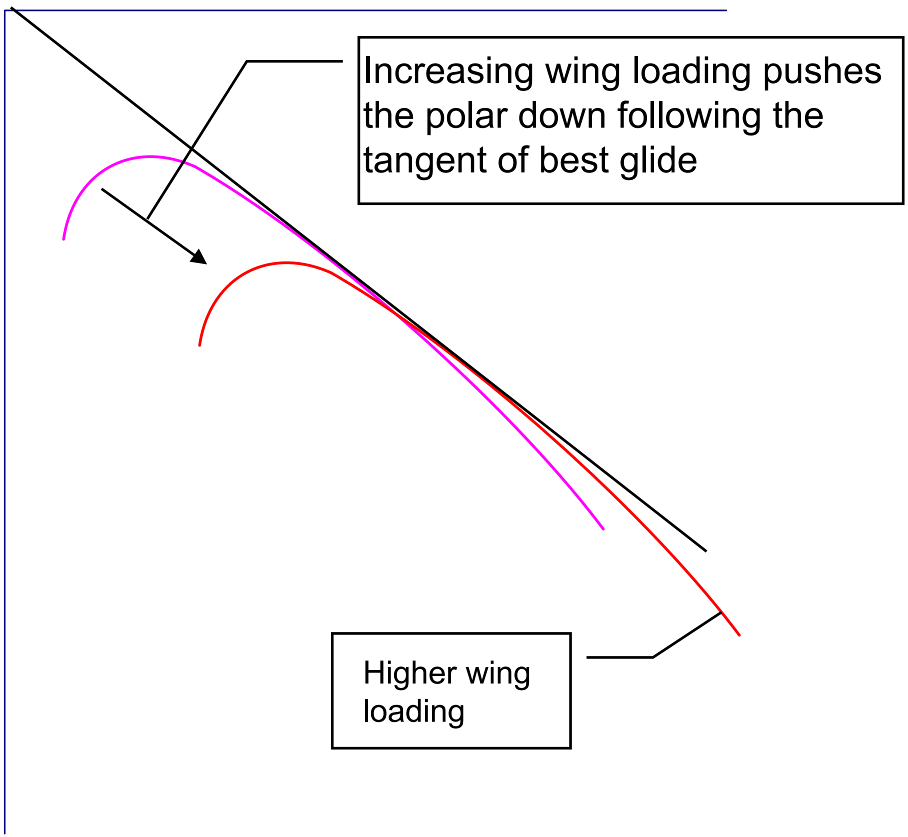
In this example, we are flying in a 100fpm thermal. Our polar tells us to slow down a little to fly at speed indicated at A





The final example shows a combination of flying an a 8mph headwind and a 150fpm sink area. The fast speed is shown at A

Effect of ballast on flight



The first thing to notice is that all speeds increase for the higher wing loading, min sink speed goes up but the min sink rate increases. Max glide ratio in still air does not change but max glide occurs at a higher speed.

Aeronautical terms

- Aspect ratio - ration of the wingspan to the chord (high aspect ratio wings are long and thin). Also Span squared divided by surface area
- Chord - Distance of airfoil trailing edge to leading edge
- Angle of attack - Measured angle from undisturbed airflow to chord line
- Dihedral - upward angling of wings from root to tip
- Anhedral - downward angling of wings from root to tip
- Centre of pressure - the point where the resultant of the lift and the drag is considered to be acting.
- Centre of Gravity – the point at which the downwards weight force is considered to be acting
- Washout - A twist in the wings from wingtip to root. (Lower A of A at tips)
- Glide angle (ratio) - expression of the efficiency of the glide. The less the angle or the greater the ratio, the better the glide.
- Min sink - the slowest possible descent rate for a glider through the air (in fpm)
- Relative wind - the apparent wind as the glider is flying.