**ROYAL CANADIAN AIR CADETS**

**PROFICIENCY LEVEL FOUR**

**INSTRUCTIONAL GUIDE**

**SECTION 3**

# EO C431.01 – EXPLAIN FLIGHT PERFORMANCE FACTORS

Total Time: 60 min

## PREPARATION

### PRE-LESSON INSTRUCTIONS

Resources needed for the delivery of this lesson are listed in the lesson specification located in A-CR-CCP-804/PG-001, *Proficiency Level Four Qualification Standard and Plan*, Chapter 4. Specific uses for said resources are identified throughout the instructional guide within the TP for which they are required.

Review the lesson content and become familiar with the material prior to delivering the lesson.

Prepare handouts for each cadet and slides of the figures located at Attachment A.

Obtain a model aircraft with articulated control surfaces and flaps for use in TPs 1–5.

### PRE-LESSON ASSIGNMENT

Nil.

### APPROACH

An interactive lecture was chosen for this lesson to clarify, emphasize and summarize flight performance factors.

## INTRODUCTION

### REVIEW

Nil.

### OBJECTIVES

By the end of this lesson the cadet shall be expected to explain flight performance factors.

### IMPORTANCE

It is important for cadets to be able to explain flight performance factors as they apply to all stages of flight. Being able to explain flight performance factors provides knowledge for potential instructional duties and is part of the fundamentals that cadets pursuing future aviation training will require.



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Use the model aircraft with articulated control surfaces and flaps throughout this lesson to illustrate flight performance factors as they are discussed.



Provide a handout of the figures to each cadet located at Attachment A.

**Teaching point 1** **Explain left turning tendencies.**

Time: 15 min Method: Interactive Lecture

## LEFT TURNING TENDENCIES

Most airplane engines turn the propeller in a clockwise direction (as seen from the pilot's seat). As a result of four different factors, this produces a tendency for the airplane to turn left. These tendencies must be factored into the design of the airplane or corrected by the pilot.

### TORQUE



Show the slide of Figure A-1 to the cadets.

Newton's Third Law of Motion states that every action has an equal and opposite reaction. This means that the clockwise rotation of the propeller is counteracted by a counter-clockwise rotation of the airplane. This reaction tends to force the left wing downwards, producing a tendency to turn left.

To correct this, airplanes can be designed with a right turning tendency, typically by having a slightly greater angle of incidence on the left wing. During takeoff (when the engine is usually running at full power) additional corrections must be applied by the pilot (rudder and / or ailerons) because of the increased amount of torque.

#### Asymmetric Thrust



Show the slide of Figure A-2 to the cadets.

At high angles of attack and high power settings (eg, takeoff) the blade of the propeller that is travelling down (the blade on the right) has a greater angle of attack than the blade that is travelling up. This creates more thrust from the right side of the propeller and creates a tendency for the aircraft to yaw or turn left.

To correct for asymmetric thrust (also known as P Factor), the pilot uses right rudder.



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**PRECESSION**




Show the slide of Figure A-3 to the cadets.

The spinning propeller acts like a gyroscope and tends to stay in the same plane of rotation, and resists any change to the plane. When a perpendicular force is applied to change the plane, a resultant force called precession is the result.

The force of precession is ahead of the plane of rotation and 90 degrees to the original applied force. Precession occurs in airplanes when the tail is lifted or lowered (eg, takeoff in a tailwheel aircraft).

To correct for precession, the pilot uses right rudder.

**SLIPSTREAM**




Show the slide of Figure A-4 to the cadets.

The air being pushed backwards by the propeller has a corkscrew motion and is called the slipstream. This causes more pressure on the left side of the fuselage and tail, and results in a tendency for the airplane to turn left.

The effects of the slipstream can be corrected by having the engine thrust line offset to the right, and / or by offsetting the vertical fin. When the airspeed of the airplane is low (eg, takeoff) the pilot may have to apply right rudder.

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**CONFIRMATION OF TEACHING POINT 1**

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**QUESTIONS**:

Q1. What four factors contribute to an airplane's left turning tendency?

Q2. Which propeller blade has a greater angle of attack at high angles of attack?

Q3. Which factor produces more pressure on the left side of the fuselage and tail?

**ANTICIPATED ANSWERS**:

A1. Torque, asymmetric thrust, precession, and slipstream.

A2. The blade moving downwards.

A3. Slipstream.



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**Teaching point 2** **Explain climbs and glides.**

Time: 10 min Method: Interactive Lecture

**CLIMBS**

During level flight at a constant airspeed, the engine produces thrust equal to drag, and the wings produce lift equal to weight. A pilot can initiate a climb by increasing the angle of attack (eg, pulling back on the stick) to produce more lift. The aircraft will climb but the airspeed will decrease.




Show the slide of Figure A-5 to the cadets.

The pilot could also initiate a climb by increasing the power setting of the engine (which would cause an increase in airspeed). If the angle of attack is not changed, the increased airspeed will create additional lift and the airplane will climb.

Once the climb is established, the aircraft is again in equilibrium. The attitude of the aircraft creates a rearward component of weight. In this state, thrust must equal drag plus the rearward component of weight and lift must equal weight, less its rearward component.

The extra power available from the engine to overcome the rearward component of weight determines the aircraft's ability to climb. As the altitude of the airplane increases, the air becomes less dense, and the available power of the engine decreases. The climb angle is reduced and further climbing eventually becomes impossible. The altitude at which this occurs is the absolute ceiling of the airplane.

**Best rate of climb ($V_Y$).** The rate of climb that gains the most altitude in the least amount of time. It is normally used during takeoff after all obstacles have been cleared.

**Best angle of climb ($V_X$).** The angle of climb that gains the most altitude in a given distance. It is used during takeoff to clear obstacles at the departure end of the runway.

**Normal climb (cruise climb).** The rate of climb recommended for prolonged climbs. It provides better cooling, visibility, and control compared to $V_Y$.

**GLIDES**




Show the slide of Figure A-6 to the cadets.

During a glide, the engine is producing minimal power and the airplane is influenced by gravity. In this state, equilibrium is achieved by balancing lift, weight, and drag.

To increase airspeed, the angle of the glide must be increased. Reducing airspeed creates a shallower glide, until the point of a stall.

A windmilling propeller (the propeller is being spun by the relative wind, not the power of the engine) can reduce the gliding distance by approximately 20 percent. Although getting the propeller to stop can increase



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the gliding range, it is difficult to perform. Additionally, the chances of restarting the engine are improved if the propeller is windmilling.

**Best glide speed for range (maximum lift / drag).** The airspeed which allows the aircraft to glide the farthest distance for altitude lost.

**Best glide speed for endurance (minimum sink).** The airspeed which allows the aircraft to remain in the air for the longest period of time.

Most airplane pilots are only concerned with the best glide speed for range airspeed as it is the airspeed usually used after an engine failure.

Sailplane (glider) pilots are concerned with both airspeeds. They use the minimum sink speed to remain in an area of rising air for as long as possible to extend the time of the flight.

**CONFIRMATION OF TEACHING POINT 2**

**QUESTIONS**:

Q1. What is $V_Y$?

Q2. What is $V_X$?

Q3. What three forces must be balanced during a glide to achieve equilibrium?

**ANTICIPATED ANSWERS**:

A1. Best rate of climb.

A2. Best angle of climb.

A3. Lift, weight, and drag.

**Teaching point 3** **Explain turns.**

Time: 5 min Method: Interactive Lecture

**TURNS**




Show the slide of Figure A-7 to the cadets.

In straight and level flight, the lift created by the wings is acting perpendicular to the wing span (vertically). To turn the aircraft, the pilot uses the ailerons to bank the aircraft in the direction of the desired turn. The lift is acting perpendicular to the wing span, but has both a horizontal and vertical component. It is the horizontal component of the lift (known as the centripetal force) that makes the aircraft turn. The opposing force (known as the centrifugal force) pulls the aircraft to the outside of the turn.

To maintain a constant altitude, the vertical component of lift must remain equal to the weight of the aircraft. This can be accomplished by increasing the angle of attack or the airspeed (by adding power). If the angle of attack is increased, additional power must be added to maintain the desired airspeed. The steeper the angle of bank, the more the angle of attack and power must be increased to maintain altitude.



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At any given airspeed, a steeper angle of bank produces:

- a higher rate of turn,
- a lower radius of turn,
- a higher stalling speed, and
- a higher load factor (G load).

At any given angle of bank, a higher airspeed produces:

- a lower rate of turn, and
- a larger radius of turn.

**Load Factors in Turns**




Show the slide of Figure A-8 to the cadets.

Turns increase the load factor. The steeper the angle of bank, the higher the load factor is. For example, a 60-degree bank produces a load factor of two. This means an aircraft that weighs 2 500 kg will have an equivalent weight of 5 000 kg. Very steep turns can produce very high load factors and may lead to structural failure.

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**CONFIRMATION OF TEACHING POINT 3**

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**QUESTIONS**:

Q1. Which component of lift makes the aircraft turn when it is banked?

Q2. What is the name of the force that pulls the aircraft towards the outside of the turn?

Q3. At any given airspeed, what does a steeper angle of bank produce?

**ANTICIPATED ANSWERS**:

A1. The horizontal component (centripetal force).

A2. The centrifugal force.

A3. A steeper angle of bank produces:

- higher rate of turn,
- lower radius of turn,
- higher stalling speed, and
- higher load factor (G load).



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**Teaching point 4** **Explain stalls, spins, and spirals.**

Time: 15 min Method: Interactive Lecture

**STALLS**



Show the slide of Figure A-9 to the cadets.

At low angles of attack, the air flows smoothly over the wing. As the angle of attack increases, the separation point between the laminar area and the turbulent area moves forward. At the critical angle of attack (determined by the design of the airfoil) the laminar flow separates from the wing and a large loss of lift (called a stall) occurs.



An airplane will stall:

- if the critical angle of attack is exceeded,
- at any airspeed if the critical angle of attack is exceeded, and
- at any attitude if the critical angle of attack is exceeded.

**Symptoms of a Stall**

As a stall is approached, there is usually a light buffeting of the airframe and controls. Lateral control of the aircraft is reduced as the ailerons lose their effectiveness in the separated airflow. When the stall is reached, lift is lost and the nose of the airplane drops.

A stall occurs gradually on most airplanes, giving the pilot time to recognize and react to the symptoms. If there is wash-out designed in the wing, the wing root will stall first and the ailerons will still be effective in the early stages of the stall.

**Factors Affecting Stalls**

**Weight.** Increasing the weight of an airplane increases the indicated airspeed at which it will stall.

**Centre of gravity.** Moving the centre of gravity forward increases the indicated airspeed at which the airplane will stall. Moving the centre of gravity rearward decreases the indicated airspeed at which it will stall. Moving the centre of gravity beyond the design limits will affect handling, stability, stall characteristics, and stall recovery.

**Turbulence.** An upward gust increases the angle of attack of the wing and could cause the airplane to exceed the critical angle at a lower airspeed than would be expected in calm air.



Show the slide of Figure A-10 to the cadets.

**Turns.** As the angle of bank in a turn is increased, the load factor and stalling speed increase. The stall speed in a turn can be calculated by multiplying the normal stall speed by the square root of the load factor.

**Flaps.** Increase the lift produced by the wing and lower the indicated airspeed at which the airplane will stall.



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**Snow, frost and ice.** Accumulations on the wing (including dirt and bugs) disrupt the airflow and add additional weight (especially accumulations of ice) causing an increase in the airspeed at which the airplane will stall and a lower critical angle of attack.

**Heavy rain.** Increases the airspeed at which an airplane will stall as the water forms a film over the surface of the wing. Raindrops create craters and waves in the film, reducing lift and increasing drag, much like frost does.

**Stall Recovery**

To recover from the stall, the wing has to produce sufficient lift. In general, the stall recovery for most light aircraft involves reducing the angle of attack (below the critical angle of attack). Applying power to increase the airspeed may also be part of the recovery process.

The pilot operating handbook (POH) for most light aircraft lists the following steps to recover from a stall:

1. Reduce the angle of attack by moving the control column forward.
2. Apply power to increase the airspeed.
3. Return to level flight.

**SPINS**




Show the slide of Figure A-11 to the cadets.

A spin may develop after a stall if one wing becomes disturbed and produces a different amount of lift. This may happen as a result of using ailerons, applying rudder to produce yaw, entering a stall in a banked attitude, or movement of a wing by turbulent air.

When one wing drops, it has a larger angle of attack and produces less lift (as it has already stalled) compared to the wing that is moving up which has a smaller angle of attack. This difference accelerates the rolling motion and autorotation sets in.




Show the slide of Figure A-12 to the cadets.

**Stages of a Spin**

A spin has three stages:

1. incipient,
2. developed, and
3. recovery.

The incipient stage occurs from the time the airplane stalls and rotation starts until the spin axis becomes vertical or nearly vertical.

In the developed stage, the angles and motions of the airplane are stabilized and the flight path is nearly vertical. During this stage the airspeed has stabilized.



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A spin is a stalled condition with a constant airspeed during the developed stage.

Spin characteristics are different for different aircraft so the technique for recovery from the specific POH must be followed. In the absence of recommendations from the manufacturer, most light airplanes can be brought out of a spin by following these steps:

1. Decrease power to idle and neutralize ailerons.
2. Apply full rudder in the opposite direction of the rotation.
3. Move the control column forward to reduce the angle of attack and unstall the wings.
4. When rotation stops, neutralize the rudder, level the wings, and ease out of the dive.

**SPIRALS**

A spiral is a steep descending turn in which the aircraft rapidly loses altitude while the airspeed rapidly increases.

The characteristics of a spiral include:

- excessive angle of bank,
- rapidly increasing airspeed, and
- rapidly increasing rate of descent.

The recovery process for a spiral is as follows:

1. Decrease power to idle and level the wings simultaneously with coordinated use of rudder and ailerons.
2. Ease out of the dive.
3. Apply power as required to maintain altitude.



A spiral is not a stalled condition. An improper recovery can cause an excessive load factor and lead to structural failure.

**CONFIRMATION OF TEACHING POINT 4**

**QUESTIONS**:

Q1. What must be exceeded in order for a stall to occur?

Q2. What does the stall speed do as the angle of bank in a turn is increased?

Q3. What is the difference between a spin and a spiral?

**ANTICIPATED ANSWERS**:

A1. The critical angle of attack.

A2. The stall speed increases.

A3. A spin is a stalled condition and has a constant airspeed. A spiral is not a stalled condition and has a rapidly increasing airspeed.



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**Teaching point 5** **Explain airspeed limitations.**

Time: 5 min Method: Interactive Lecture

To reduce the risk of structural failure from an excessive load factor, airplane manufacturers publish a number of airspeed limitations in the POH.

**Never exceed (maximum permissible dive) speed ($V_{NE}$).** The maximum airspeed at which the airplane may be operated in smooth air.

**Maximum structural cruise (normal operating limit) speed ($V_{NO}$).** The maximum cruise airspeed at which the airplane was designed to operate.

**Manoeuvring speed ($V_A$).** The maximum airspeed at which the flight controls can be fully deflected without causing structural damage.

**Maximum gust intensity speed ($V_B$).** The maximum airspeed for penetration of gusts of maximum intensity. For most light airplanes $V_A$ and $V_B$ are the same.

**Maximum flaps extended speed ($V_{FE}$).** The maximum airspeed at which the airplane may be operated with the flaps extended.

**CONFIRMATION OF TEACHING POINT 5**

**QUESTIONS**:

Q1. What does $V_{NE}$ specify?

Q2. What is the maximum airspeed at which the flight controls can be fully deflected?

Q3. What does $V_{FE}$ specify?

**ANTICIPATED ANSWERS**:

A1. The maximum airspeed at which the airplane may be operated in smooth air.

A2. $V_A$.

A3. The maximum airspeed at which the airplane may be operated with the flaps extended.

**END OF LESSON CONFIRMATION**

**QUESTIONS**:

Q1. What happens to the load factor in a turn?

Q2. What are the characteristics of a spiral?

Q3. What is the maximum cruise airspeed at which the airplane was designed to operate?

**ANTICIPATED ANSWERS**:

A1. The load factor increases.



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A2. The characteristics of a spiral include:

- excessive angle of bank,
- rapidly increasing airspeed, and
- rapidly increasing rate of descent.

A3. $V_{NO}$.

## CONCLUSION

### HOMEWORK / READING / PRACTICE

Nil.

### METHOD OF EVALUATION

Nil.

### CLOSING STATEMENT

Future aviation training and instructional duties depend on knowledge of left turning tendencies, climbs, glides, turns, stalls, spins, spirals and airspeed limitations.

### INSTRUCTOR NOTES / REMARKS

Cadets who are qualified Advanced Aviation may assist with this instruction.

## REFERENCES

C3-116 ISBN 0-9680390-5-7 MacDonald, A. F., & Peppler, I. L. (2000). *From the ground up: Millennium edition*. Ottawa, ON: Aviation Publishers Co. Limited.

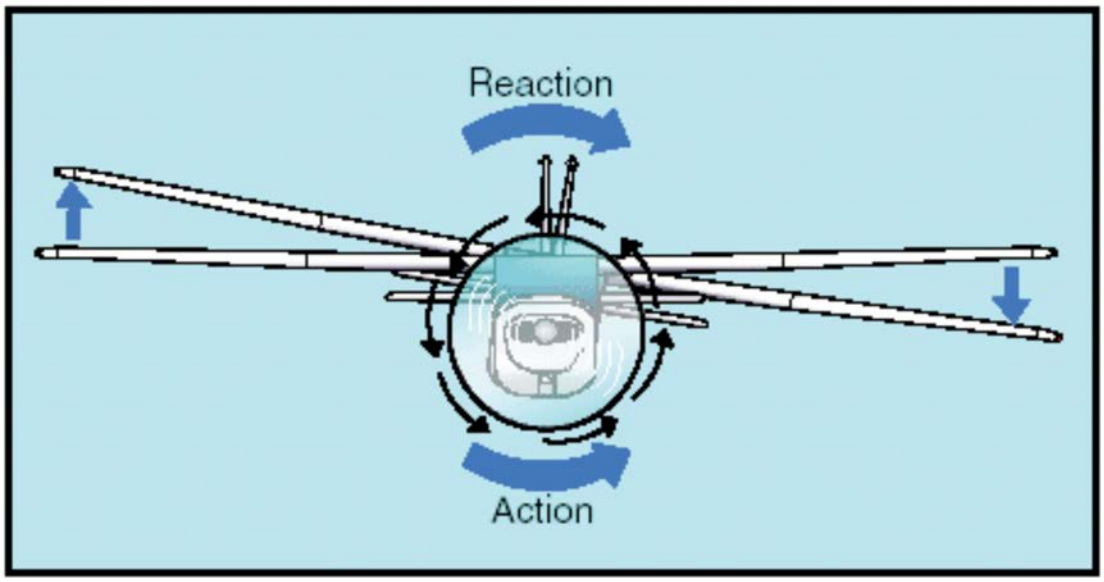


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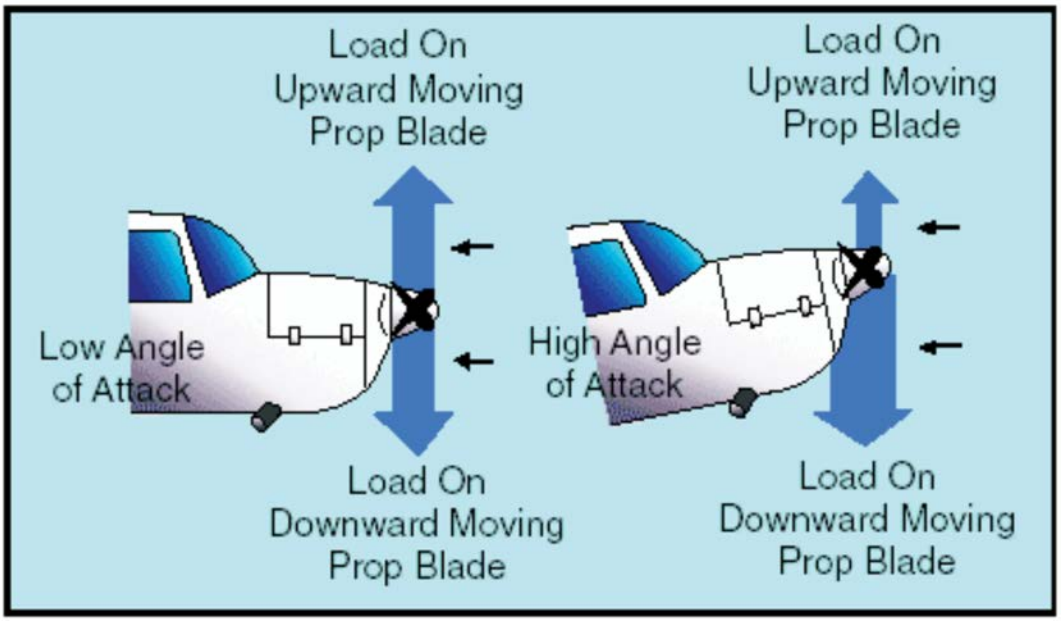


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*Note. From "Propeller Aerodynamics", Free Online Private Pilot Ground School. Retrieved November 6, 2008, from http://www.free-online-private-pilot-ground-school.com/propeller-aerodynamics.html*

Figure A-1 Torque Reaction

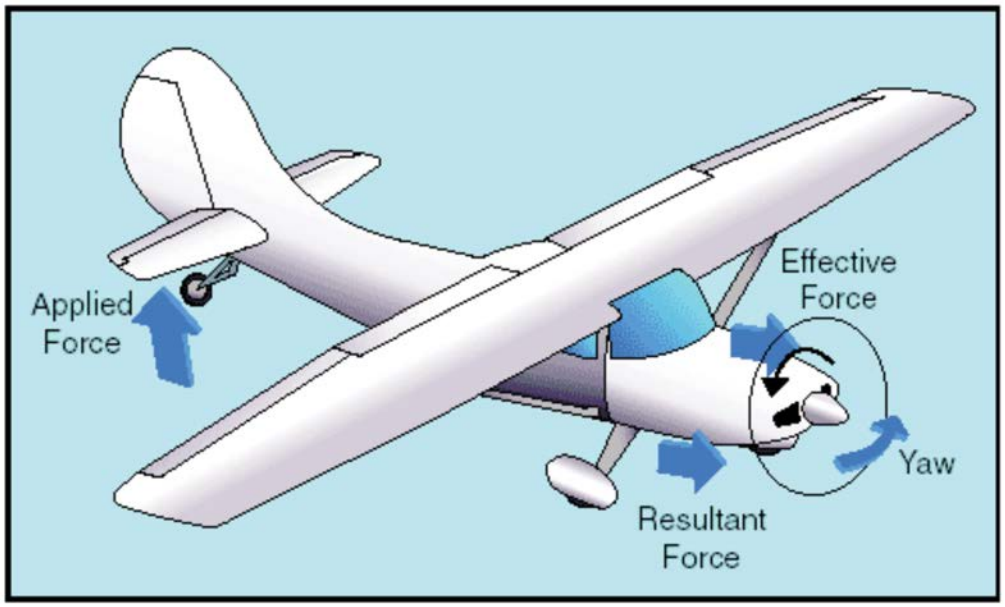



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Figure A-2 Asymmetric Thrust (P Factor)

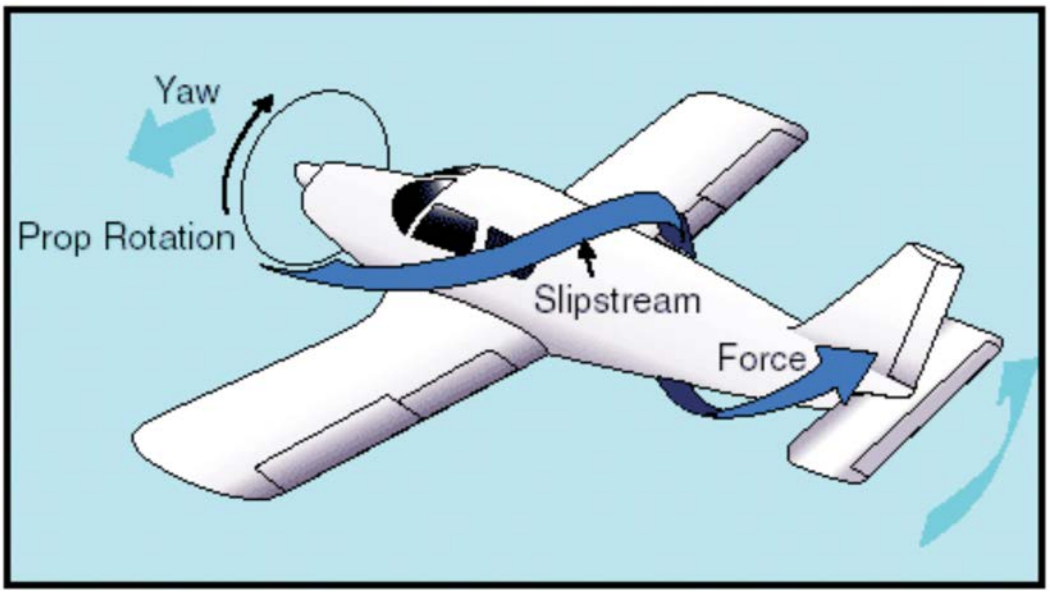


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Figure A-3 Precession When the Tail is Lifted

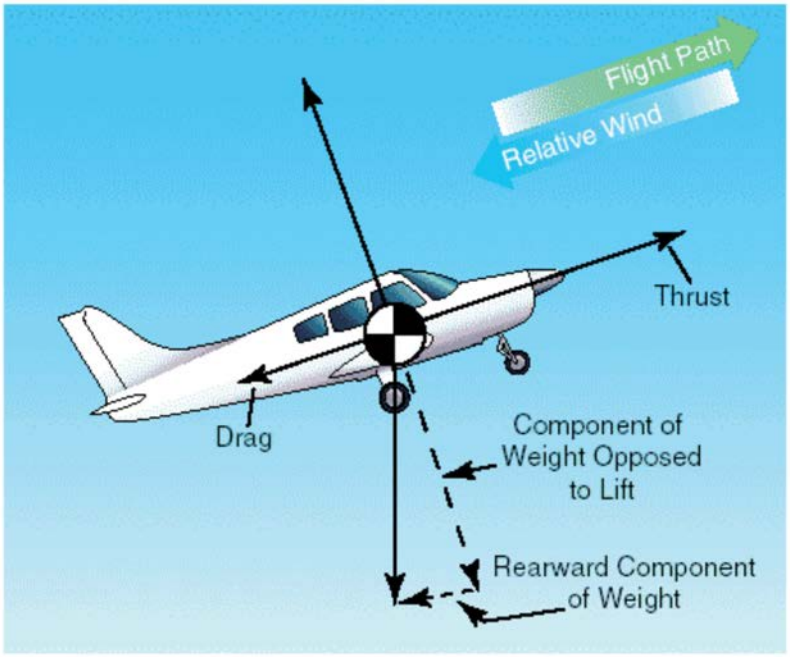



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Figure A-4 Slipstream

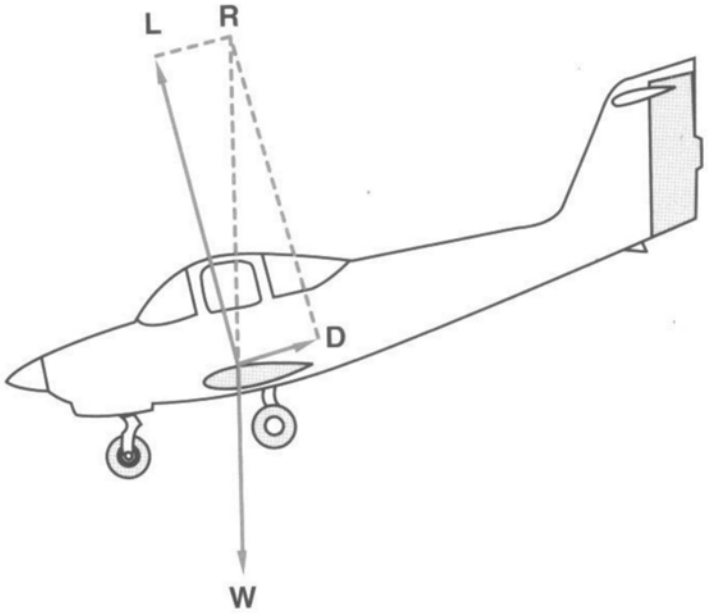


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Figure A-5 Forces in a Climb

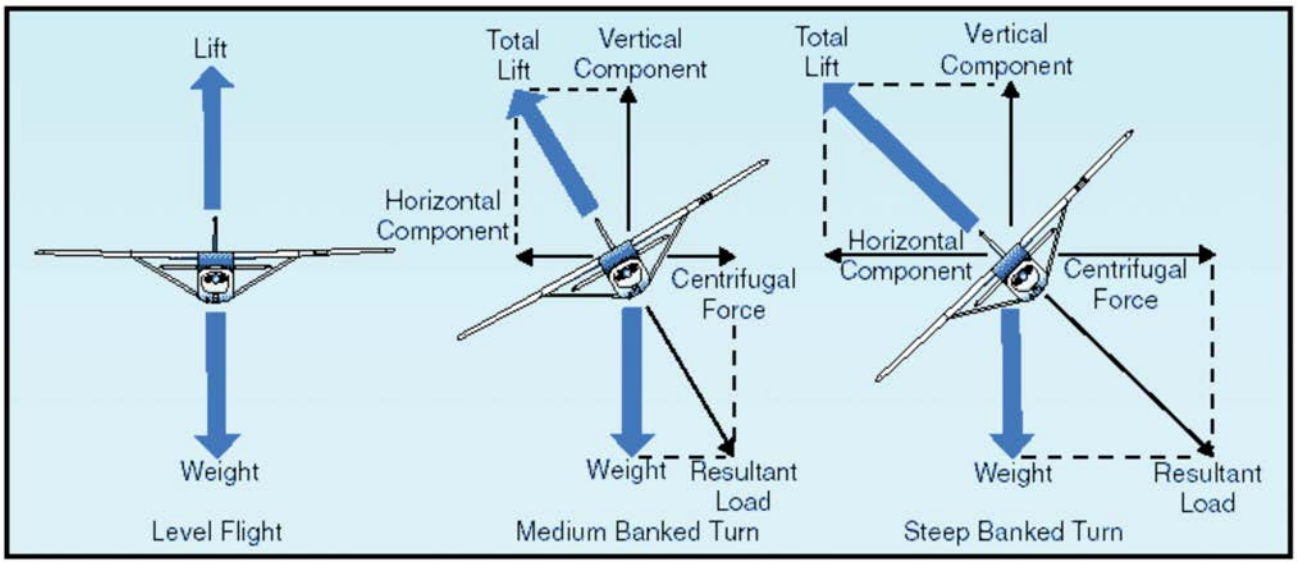



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Figure A-6 Forces in a Glide

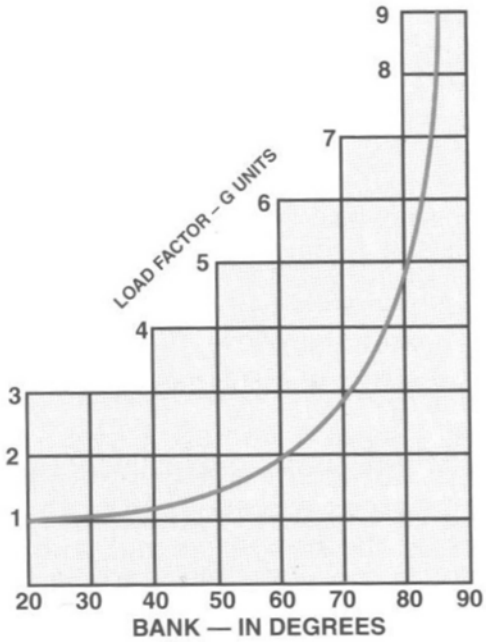


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Figure A-7 Forces in a Turn

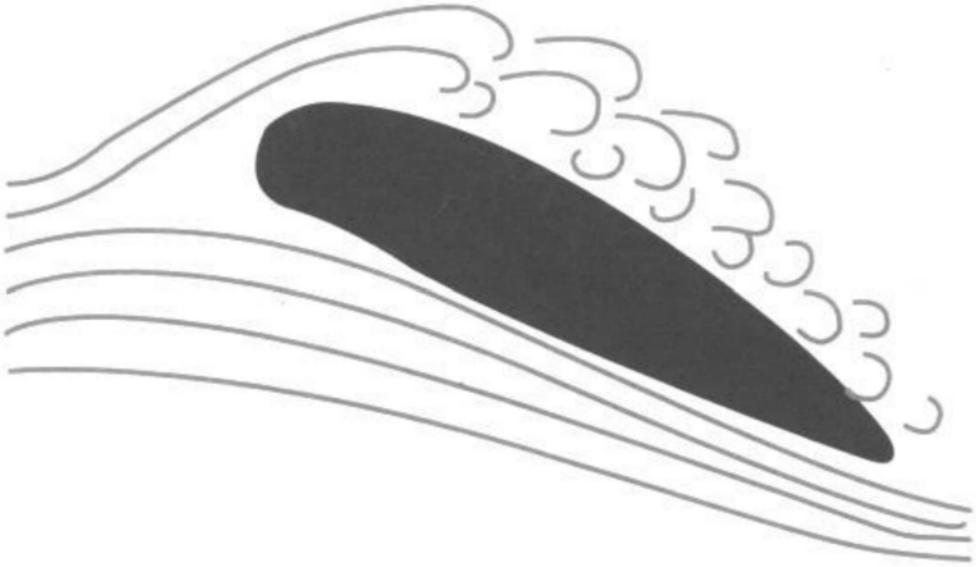



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Figure A-8 Load Factors in Turns



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Figure A-9 Stall

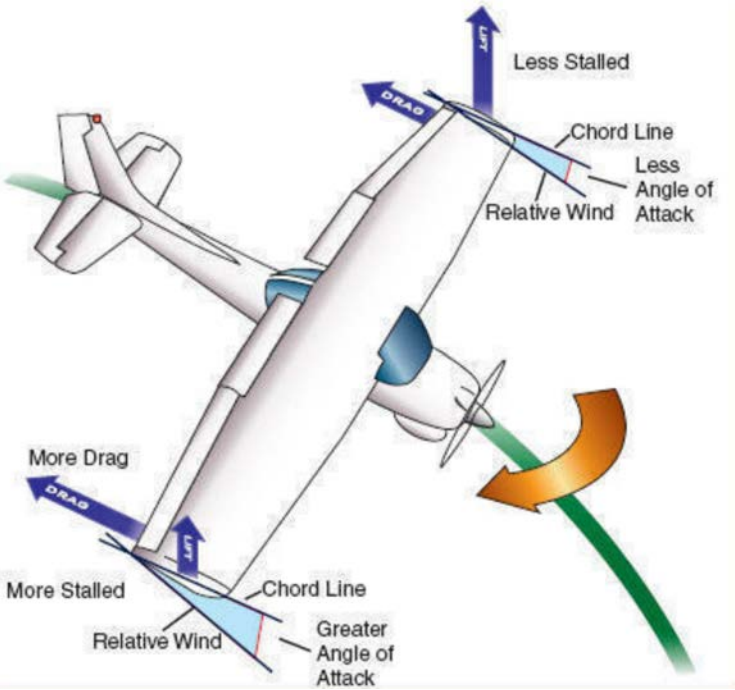
| STALL SPEED, POWER OFF | | | |
|---|---|---|---|
| ***GROSS WEIGHT*** ***2800 LBS.*** | ANGLE OF BANK | | |
| CONFIGURATION | 0° | 30° | 60° |
| FLAPS UP | 64 | 69 | 91 |
| FLAPS 20° | 57 | 61 | 81 |
| FLAPS 40° | 55 | 59 | 78 |

*Note. From From the Ground Up: Millennium Edition (p. 35), by A. F. MacDonald and I. L. Peppler, 2000, Ottawa, ON: Aviation Publishers Co. Limited. Copyright 2000 by Aviation Publishers Co. Limited.*

Figure A-10 Stall Speed in Turns

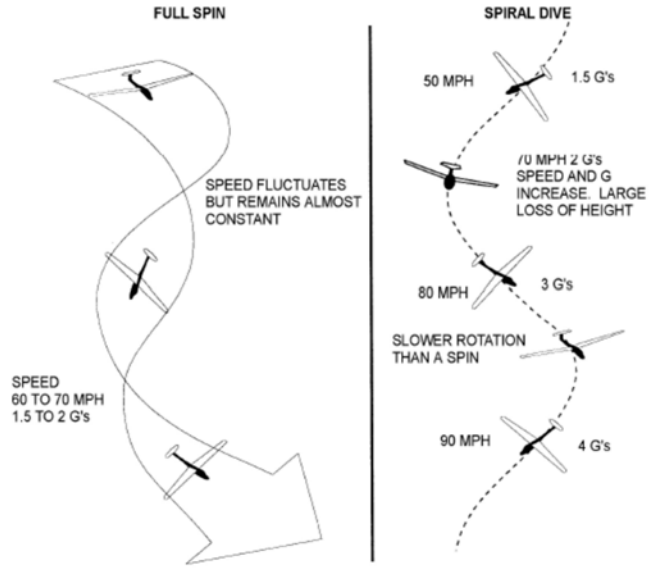


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Verify against the official publication.




*Note. From "What is a Spin?", Over the Airwaves. Retrieved November 12, 2008, from http://overtheairwaves.com/Vol3-111.jpg*

Figure A-11 Spin




*Note. From Air Cadet Gliding Program Manual (p. 6-6-4), by Air Force Training, 2009, Ottawa, ON: Department of National Defence.*

Figure A-12 Spin and Spiral Recognition



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