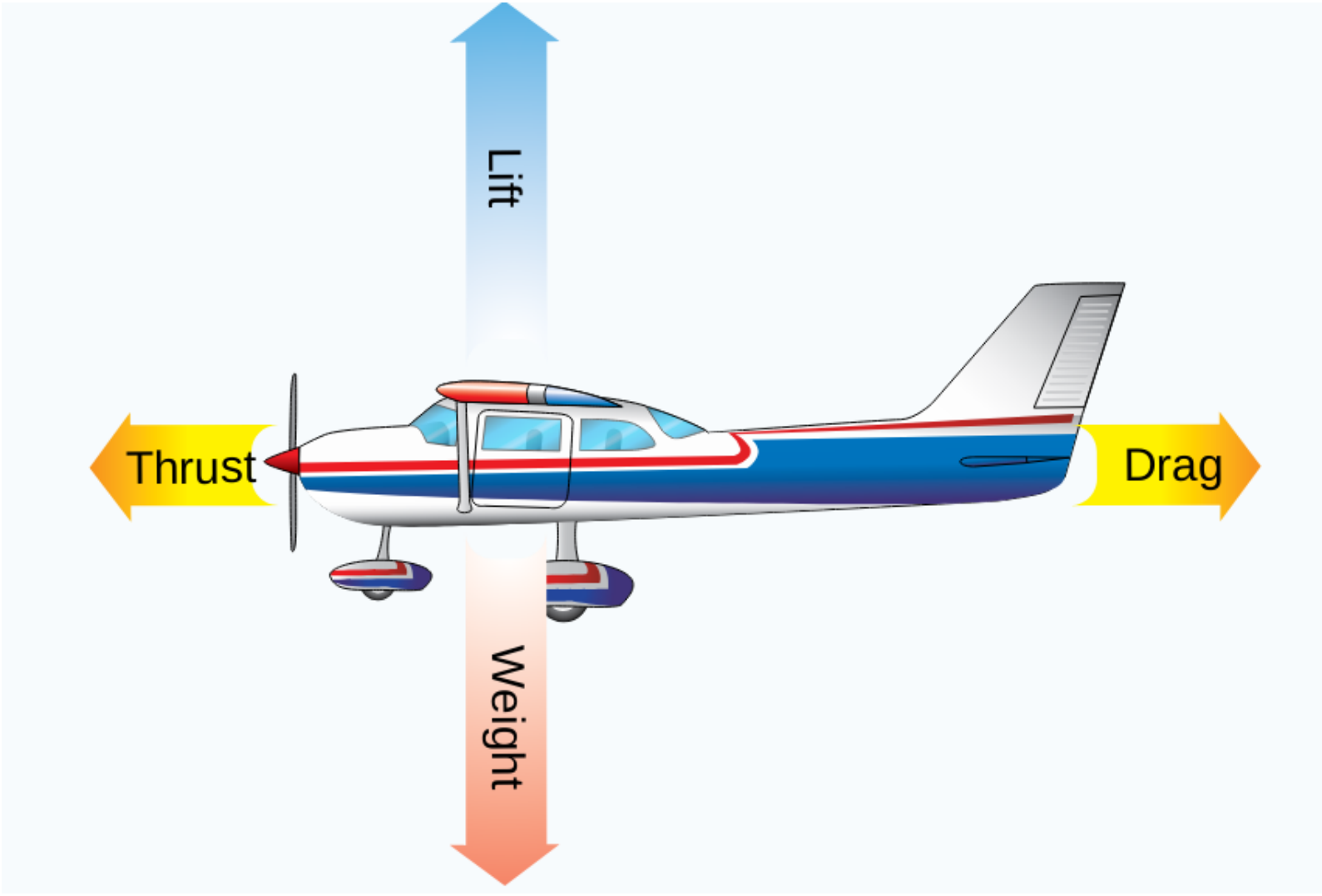
Basic Aerodynamics

Chapter 1

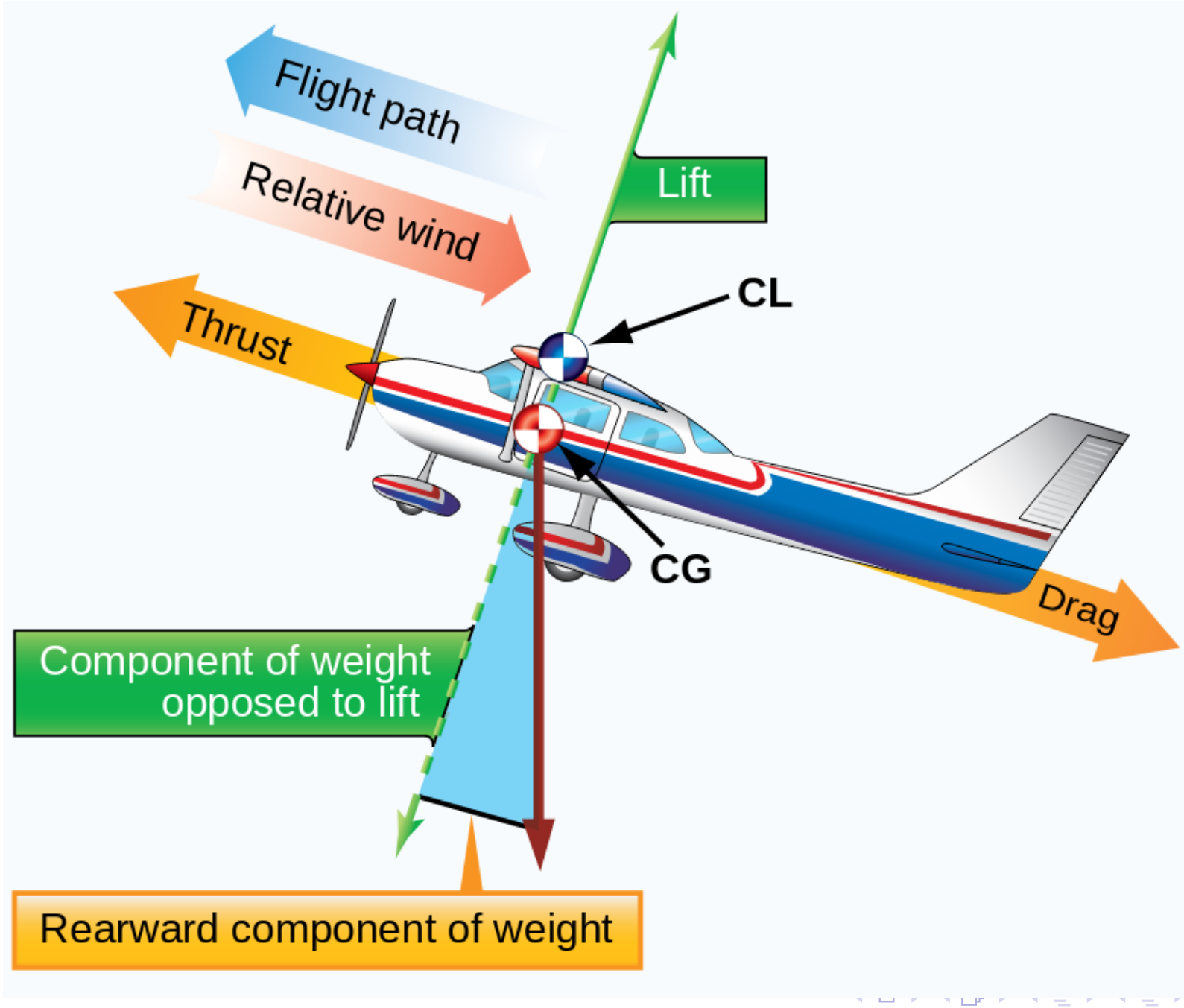
Questions

1. What are the four aerodynamic forces?
2. Consider an aircraft flying a straight path in a steady descent. How do the four forces relate to each other?
3. What are the four primary control inputs of an aircraft?
4. If an airplane stalls at a 20° angle of attack in level flight, what angle of attack will it stall in a 60° bank?
5. Why does P-factor act in the opposite direction in Russian-built aircraft?
6. Is the way an airplane turns more like a car or bicycle and why?
7. How is a spin different from a spiral dive?

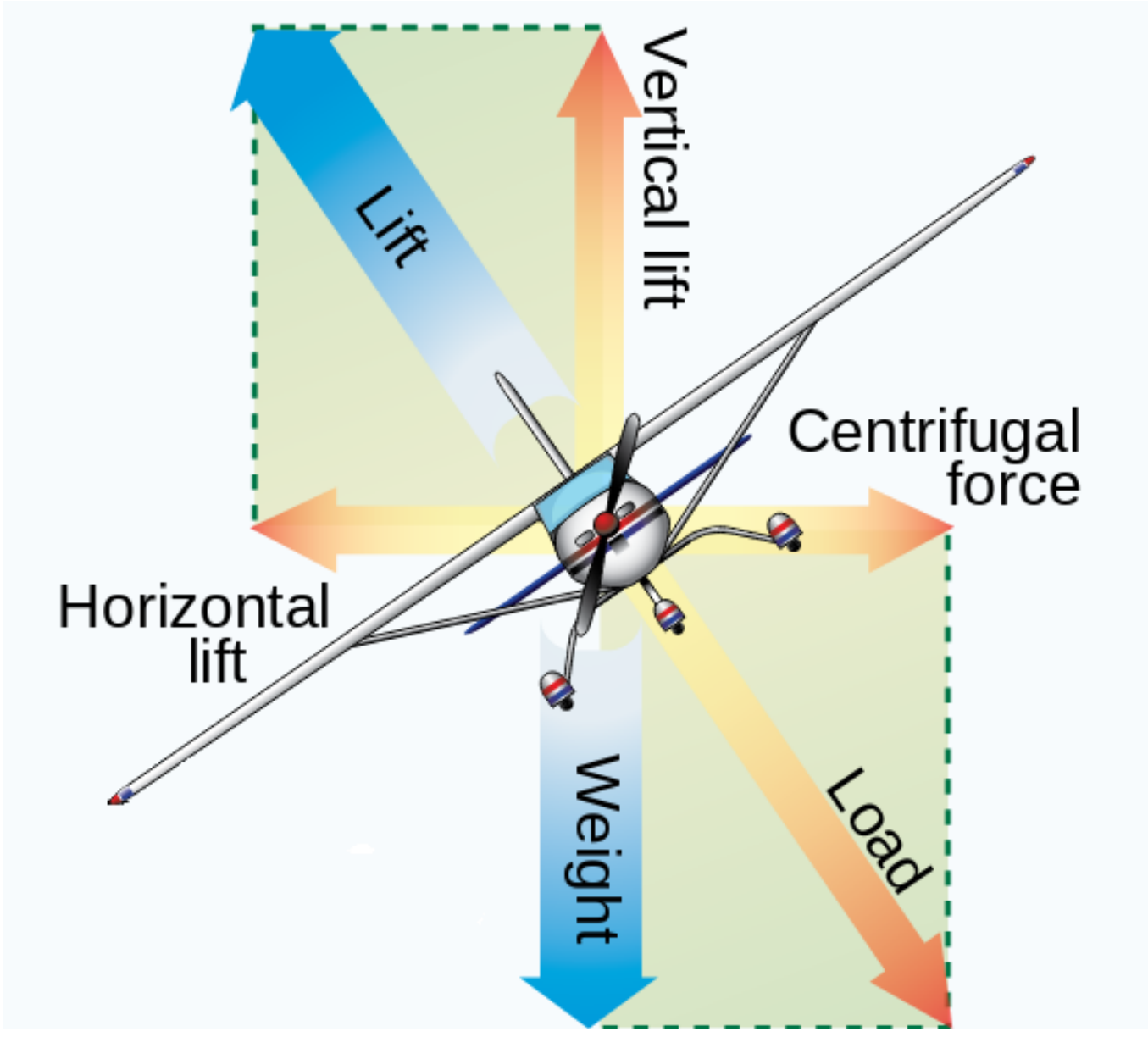
Level Flight



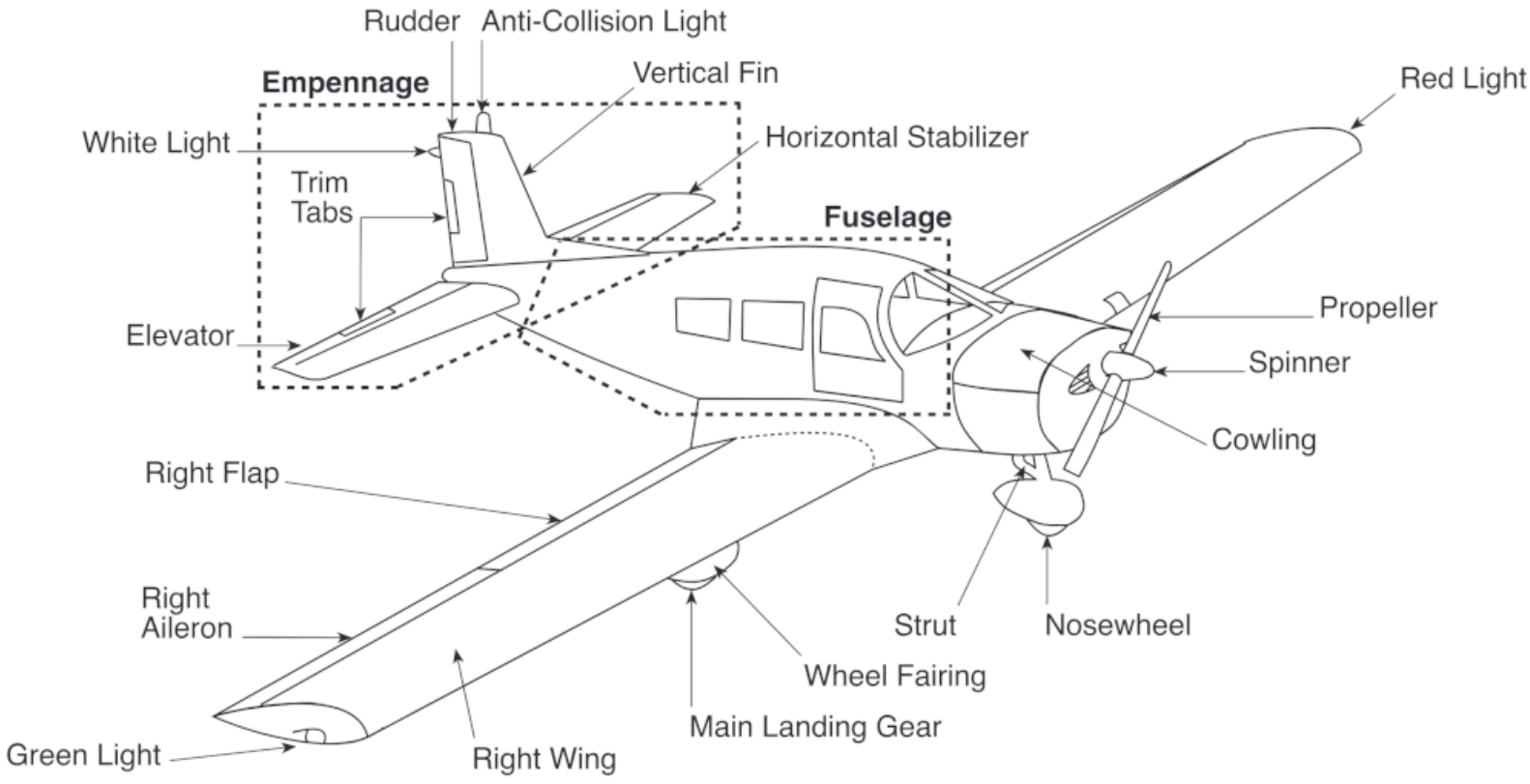
Climbing


Flight path
Relative wind
Lift
CL
Thrust
CG
Drag
Component of weight
opposed to lift
Rearward component of weight

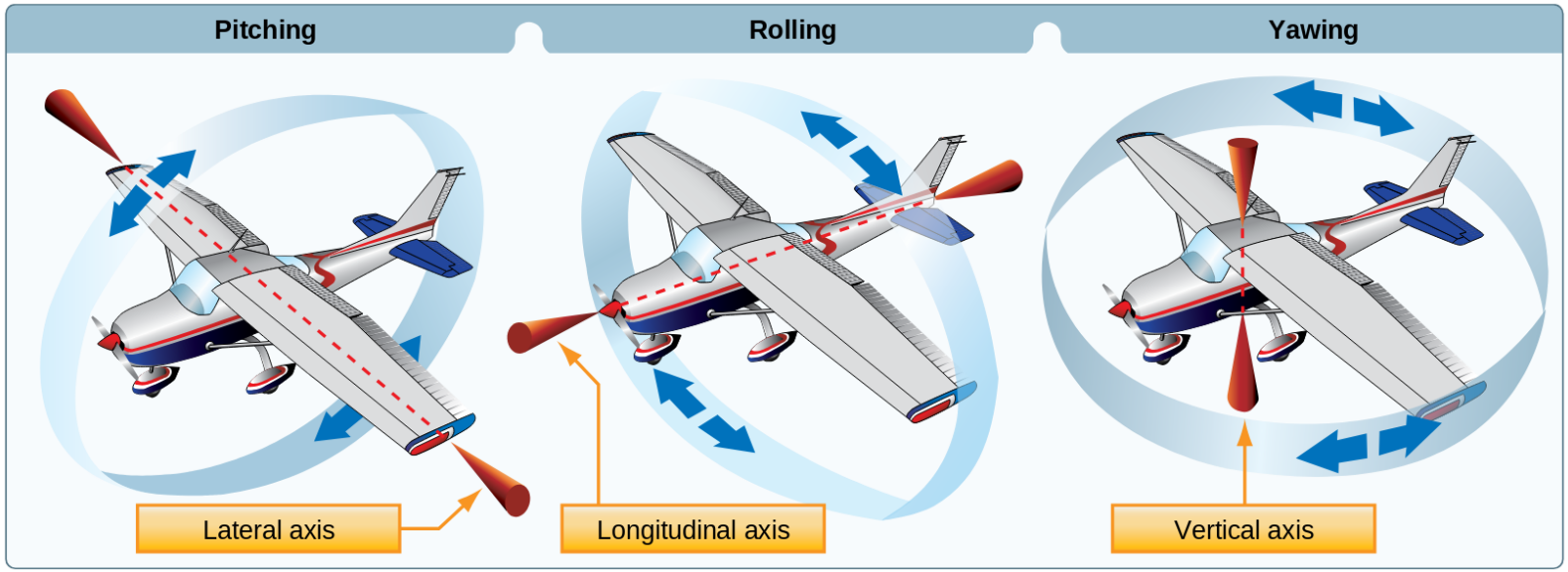
Turn


Lift
Vertical lift
Centrifugal force
Horizontal lift
Weight
Load

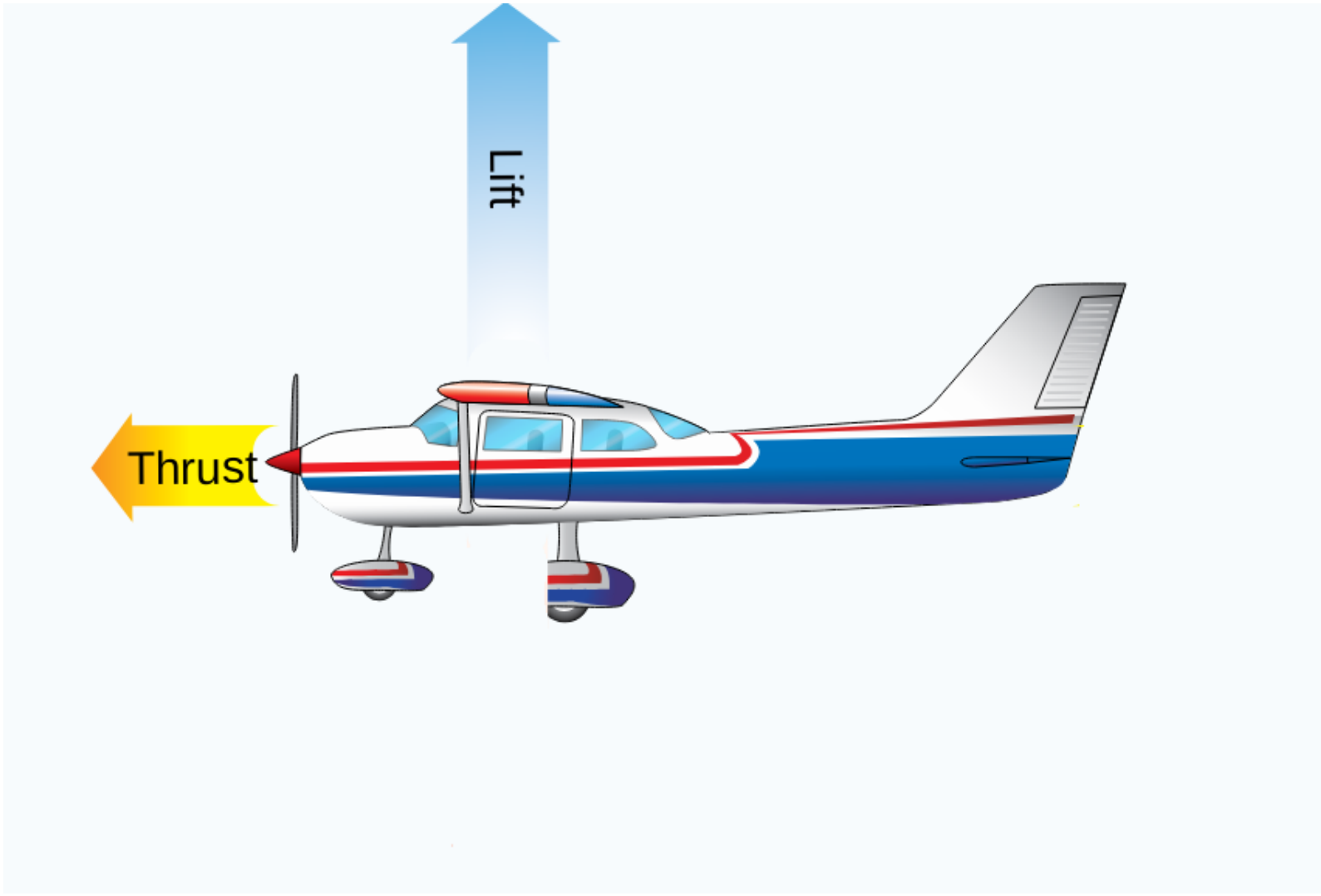
Airframe


Rudder
Anti-Collision Light
Empennage
Vertical Fin
Red Light
White Light
Horizontal Stabilizer
Trim
Tabs
Fuselage
Propeller
Elevator
Spinner
Cowling
Right Flap
Right
Aileron
Strut
Nosewheel
Wheel Fairing
Main Landing Gear
Green Light
Right Wing

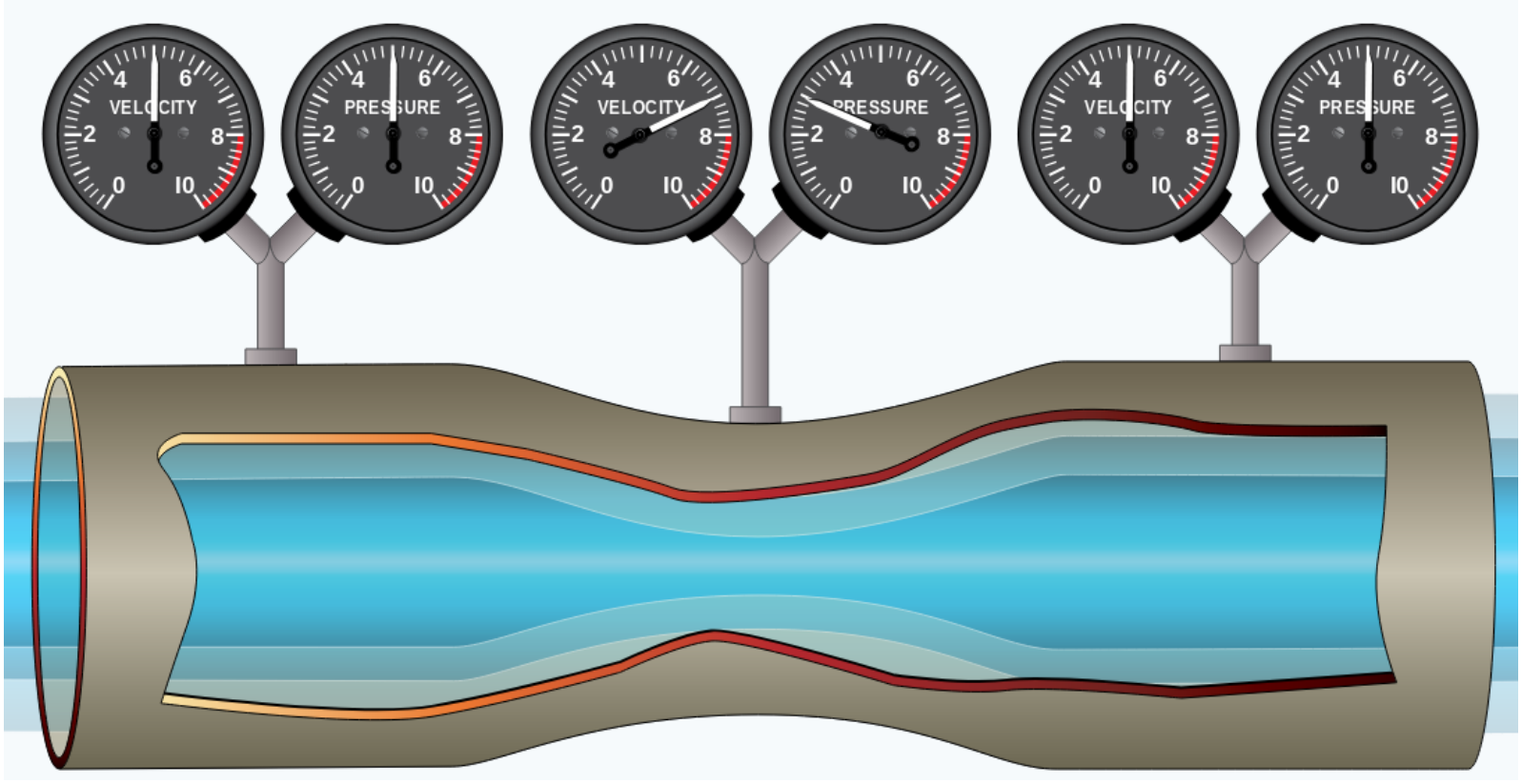
Axis and Controls



Level Flight

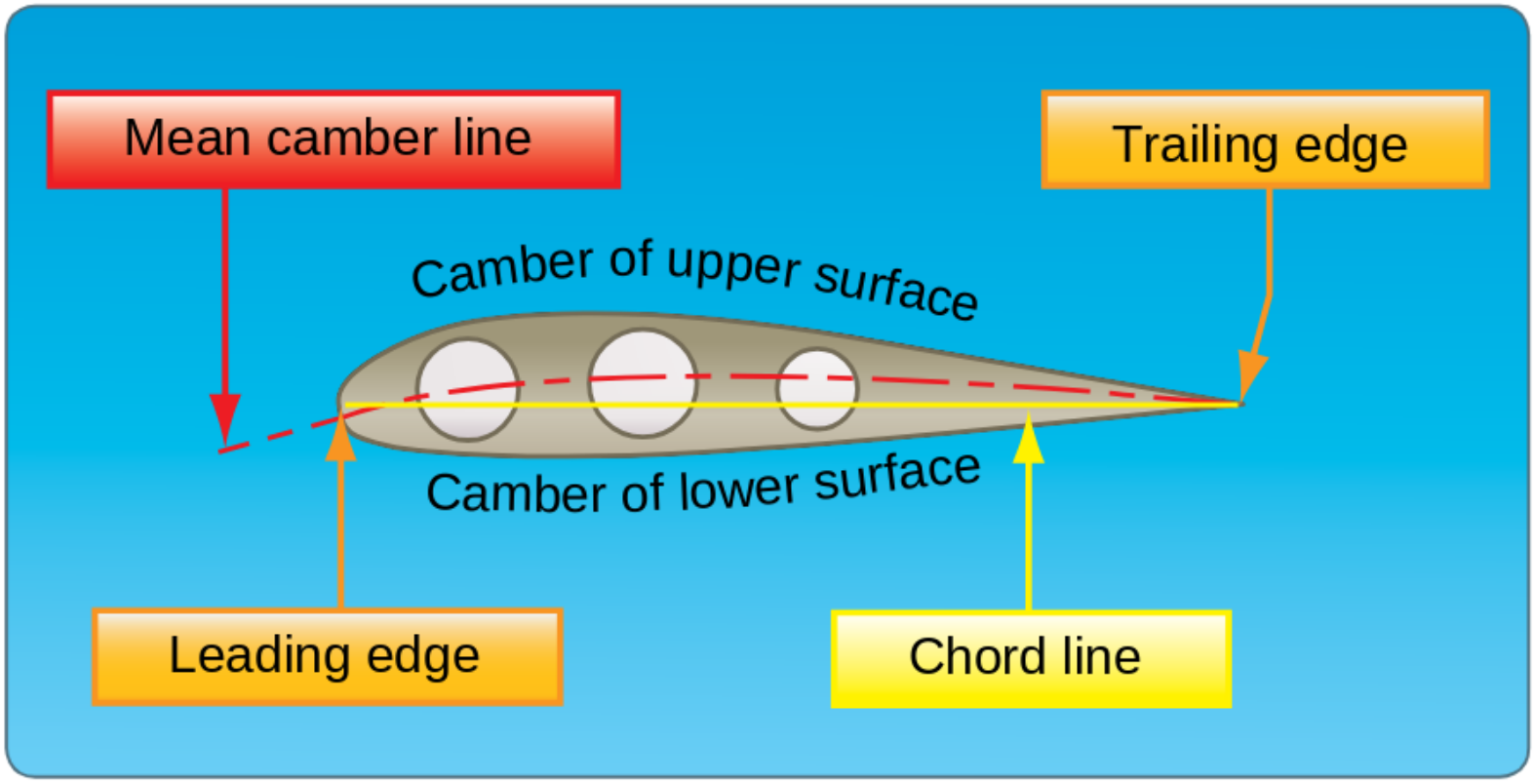


Bernoulli Effect

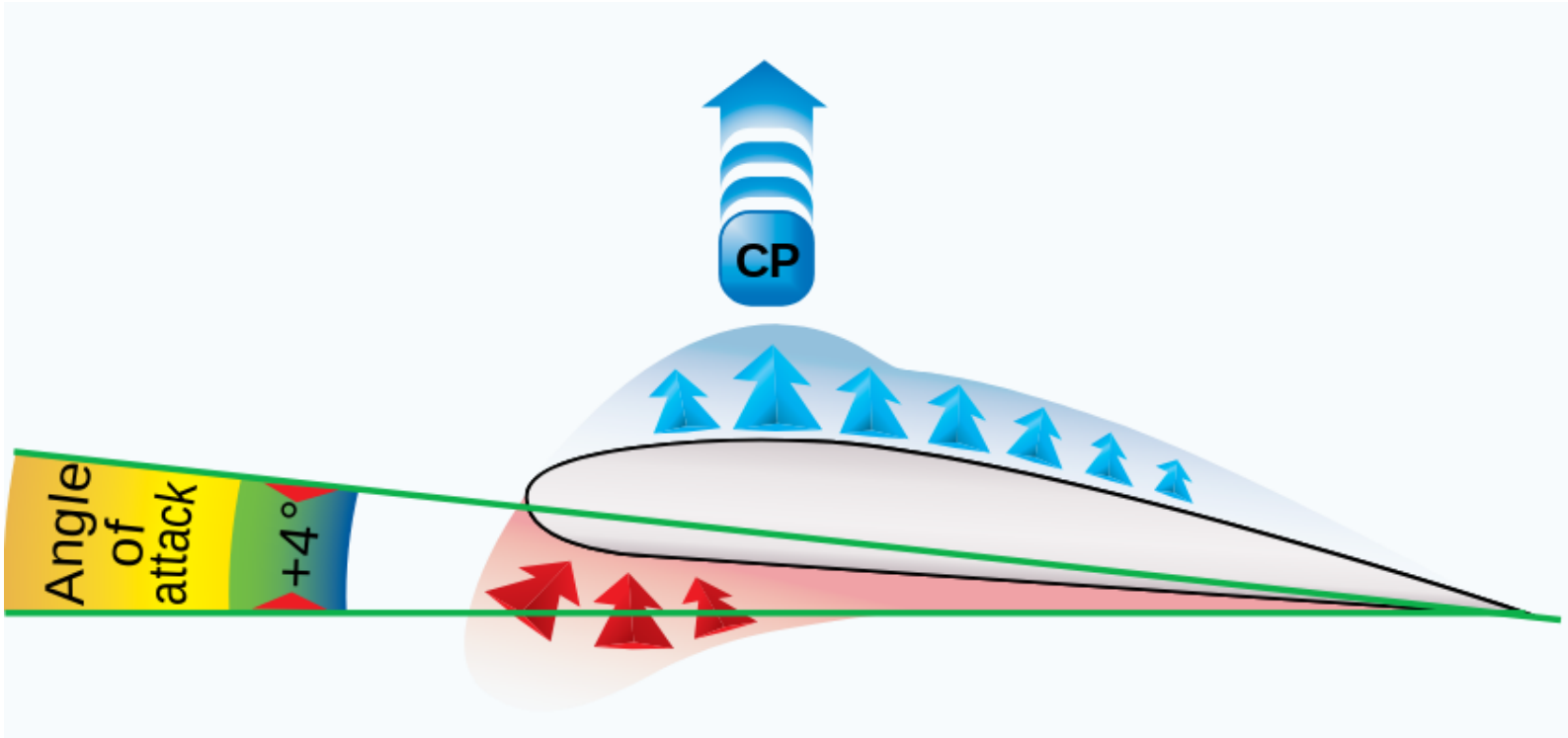


Okay, sure, it is the first integral of Newton's Second Law of Motion.

Airfoil


Mean camber line
Trailing edge
Camber of upper surface
Camber of lower surface
Leading edge
Chord line

Airfoil



Lift

$$L = \frac{C_L \cdot \rho \cdot v^2 \cdot s}{2}$$

C_L is the Coefficient of Lift

ρ is air (fluid) density

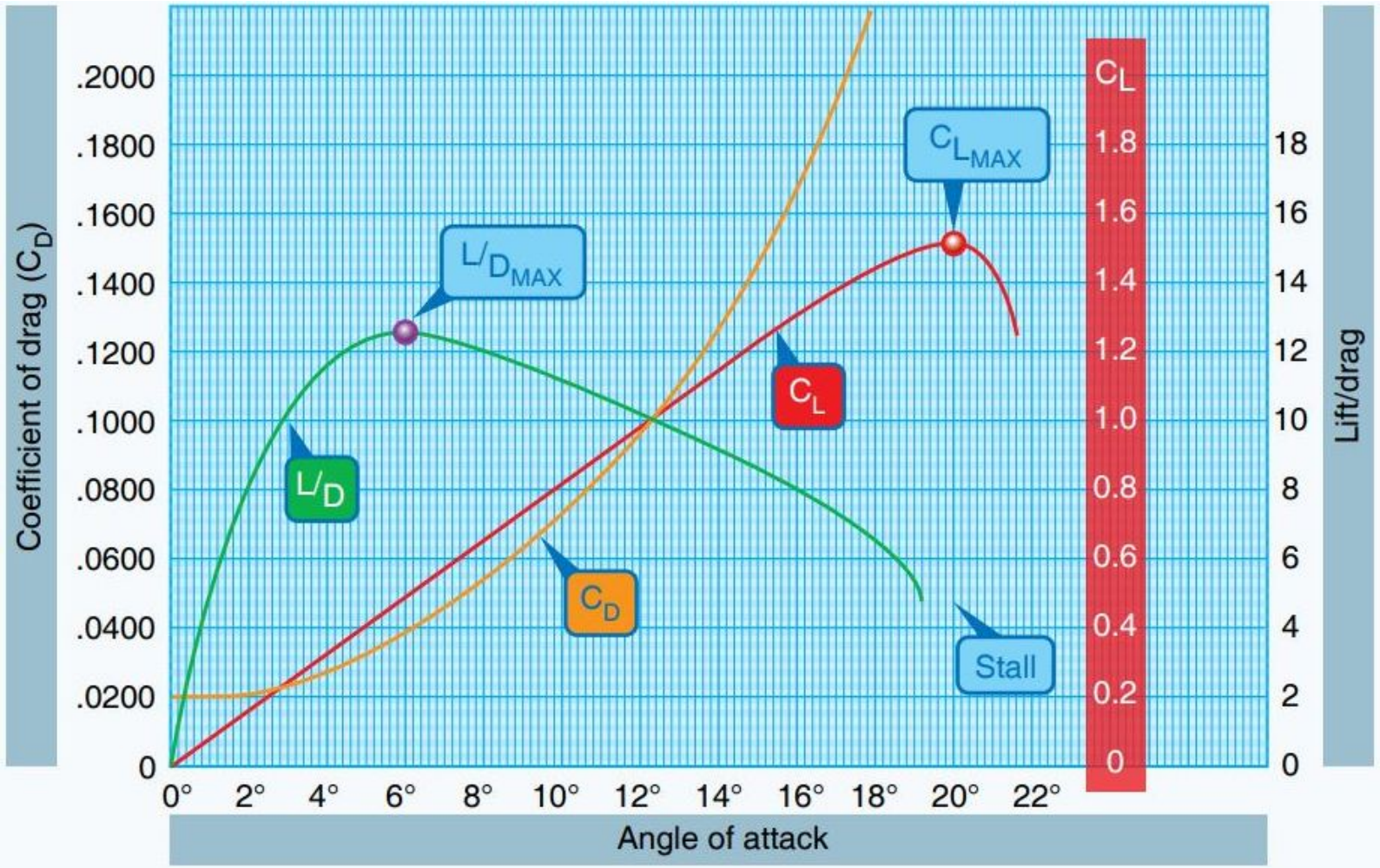
v is velocity

s is the surface area of the wing

Lift

$$
\begin{aligned}
L &= \frac{C_L \cdot \rho \cdot v^2 \cdot s}{2} \\
&= \frac{C_L \times \rho \times v^2 \times s}{2} \\
&= \frac{C_L \rho v^2 s}{2}
\end{aligned}
$$

Lift


Coefficient of drag (C_D)
.2000
.1800
.1600
.1400
.1200
.1000
.0800
.0600
.0400
.0200
0
L/D_{MAX}
L/D
C_D
C_L
$C_{L_{MAX}}$
Stall
C_L
1.8
1.6
1.4
1.2
1.0
0.8
0.6
0.4
0.2
0
18
16
14
12
10
8
6
4
2
0
Lift/drag
0°
2°
4°
6°
8°
10°
12°
14°
16°
18°
20°
22°
Angle of attack

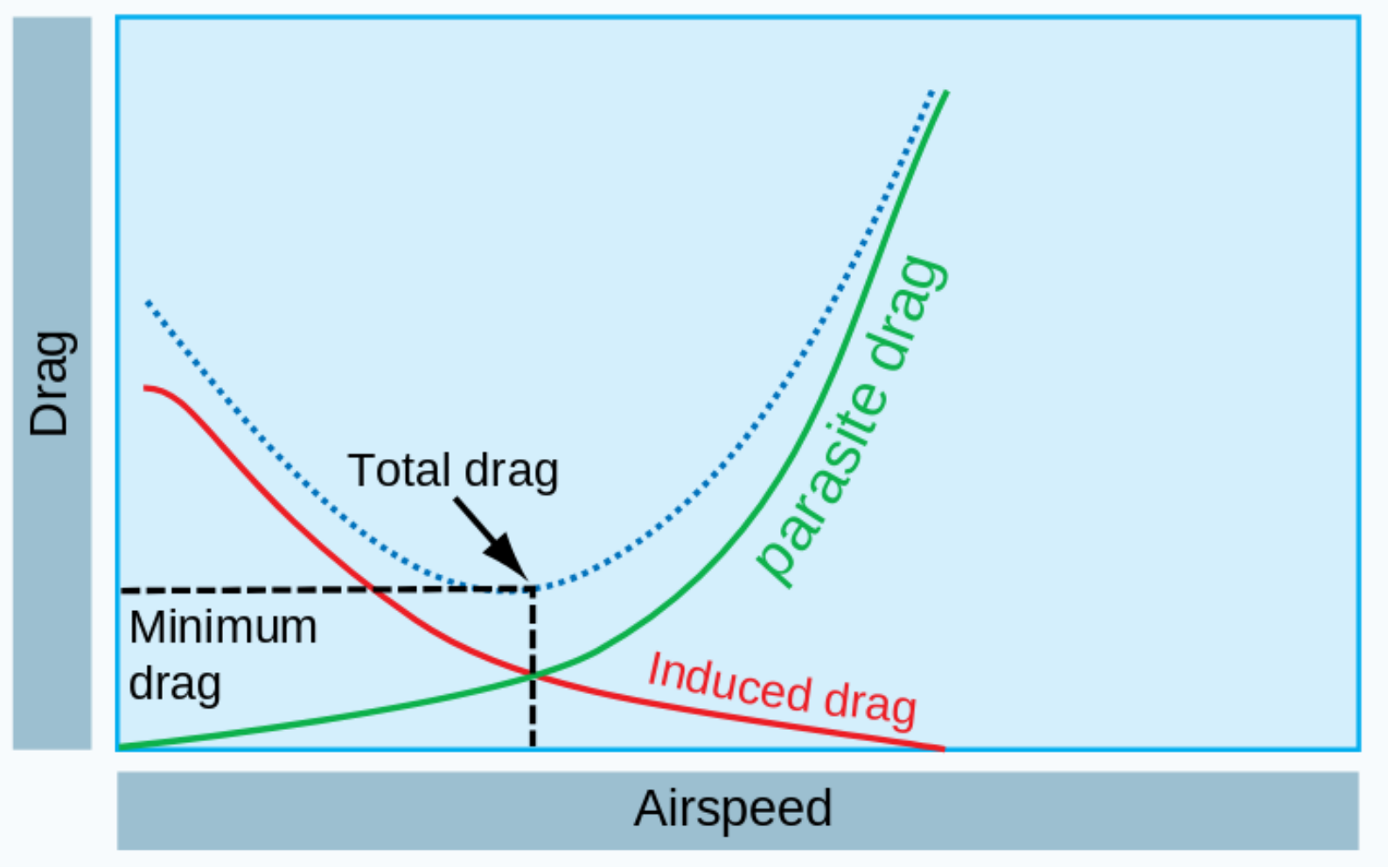
Lift

$$L = \frac{C_L \rho v^2 s}{2}$$
$$W = \frac{C_L \rho v^2 s}{2}$$
$$\approx R_1(R_2 - R_3 A)\alpha v^2$$

Where W is weight, R_n are some positive constants, and A is roughly altitude. Note that this is a gross approximation of density.

- As altitude increases, angle of attack increases or true airspeed increases.
- As true airspeed decreases, angle of attack increases.

Drag Curve


Drag
Total drag
parasite drag
Minimum
drag
Induced drag
Airspeed

Wingtip Vortexes

Wingtip Vortexes

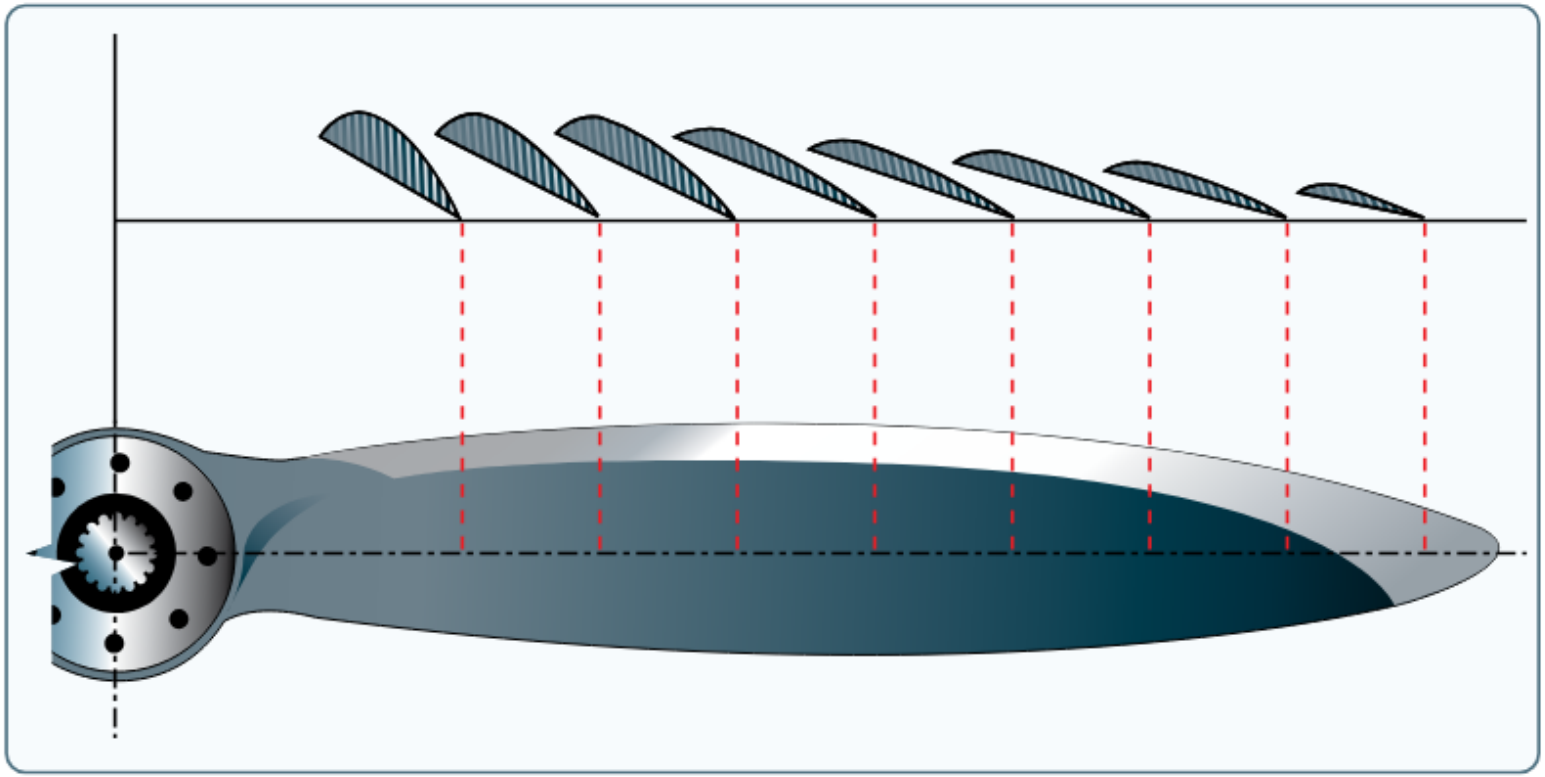
Wingtip Vortexes

Photo by Glenn Beltz

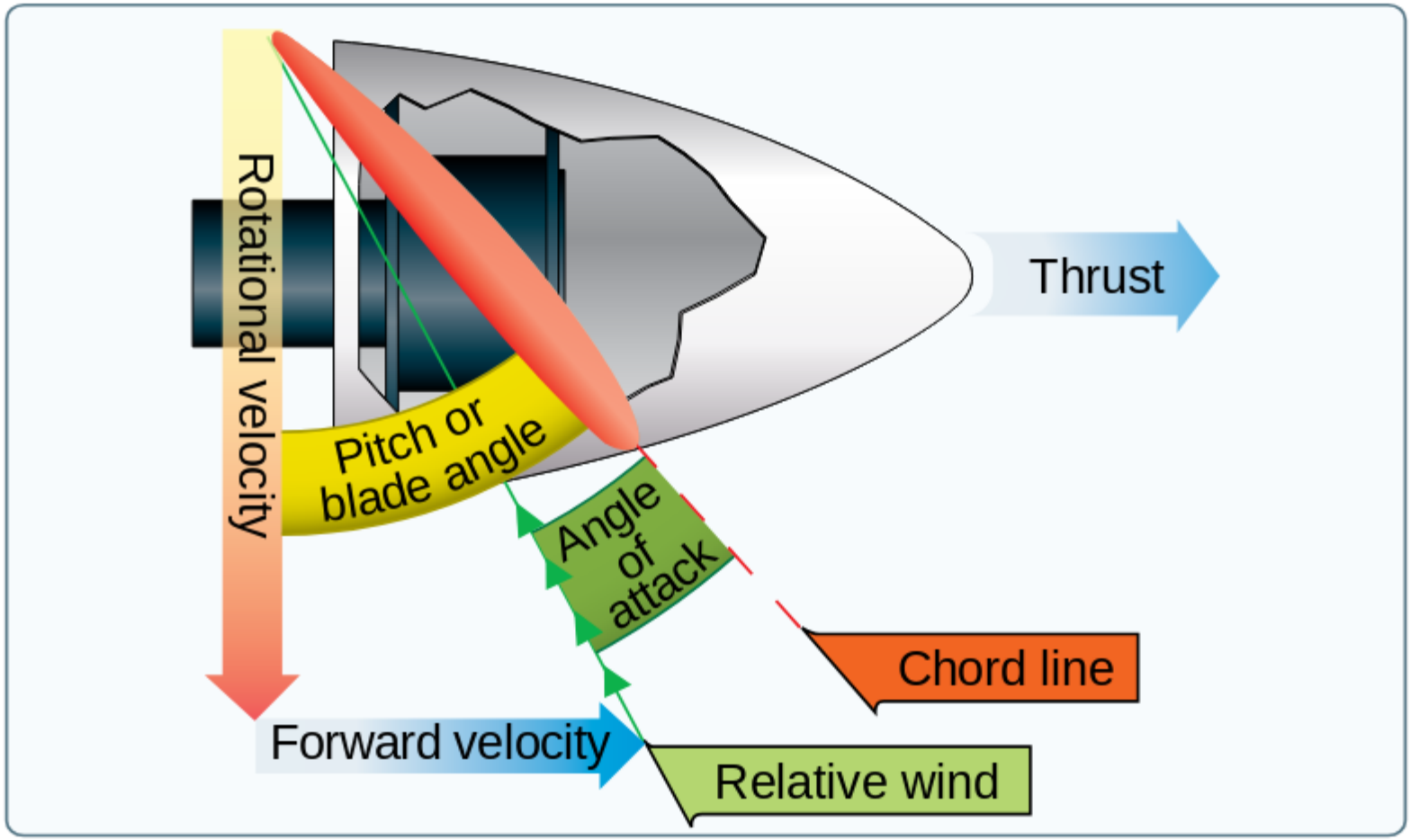
Wingtip Vortexes

Photo by Peter Gronemann

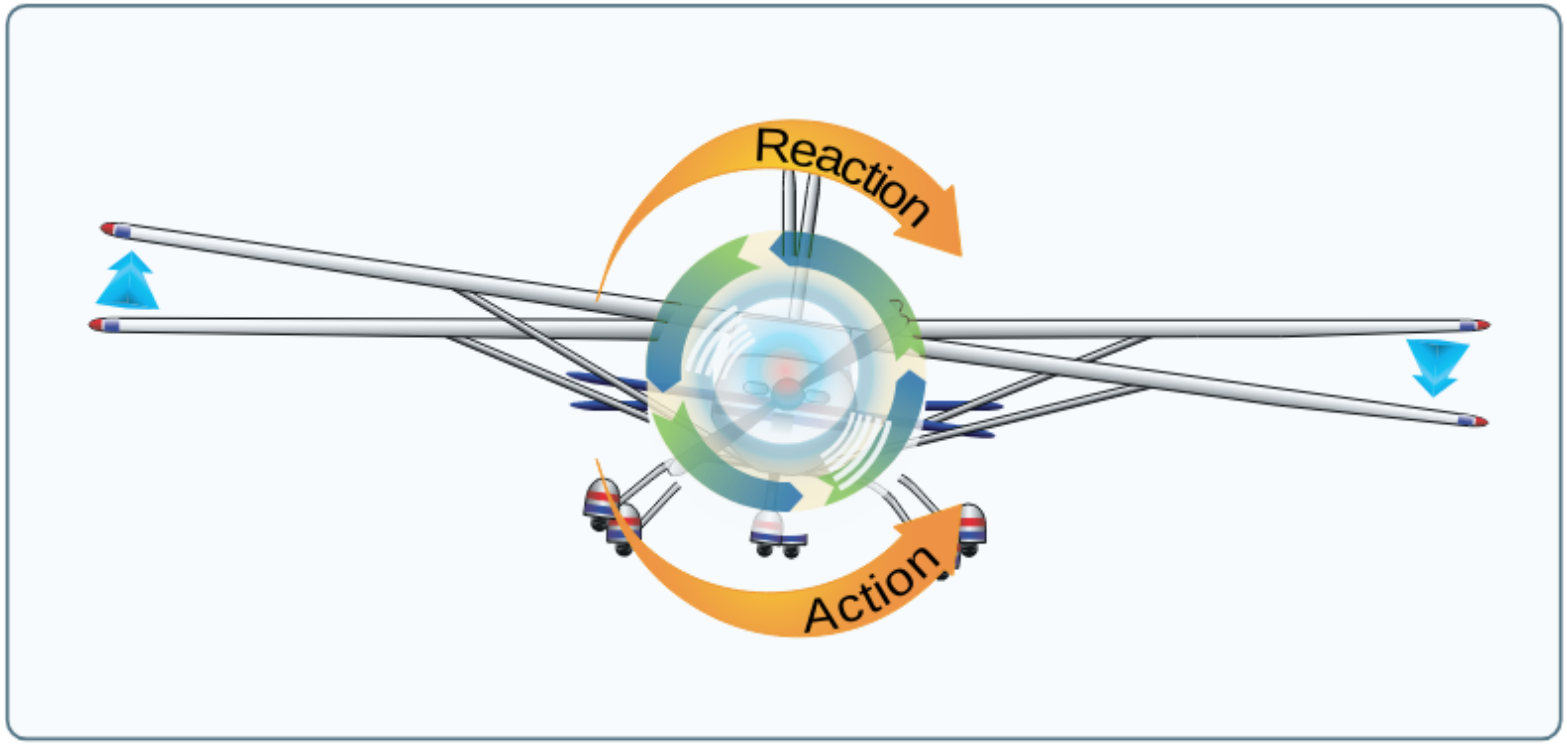
Propeller



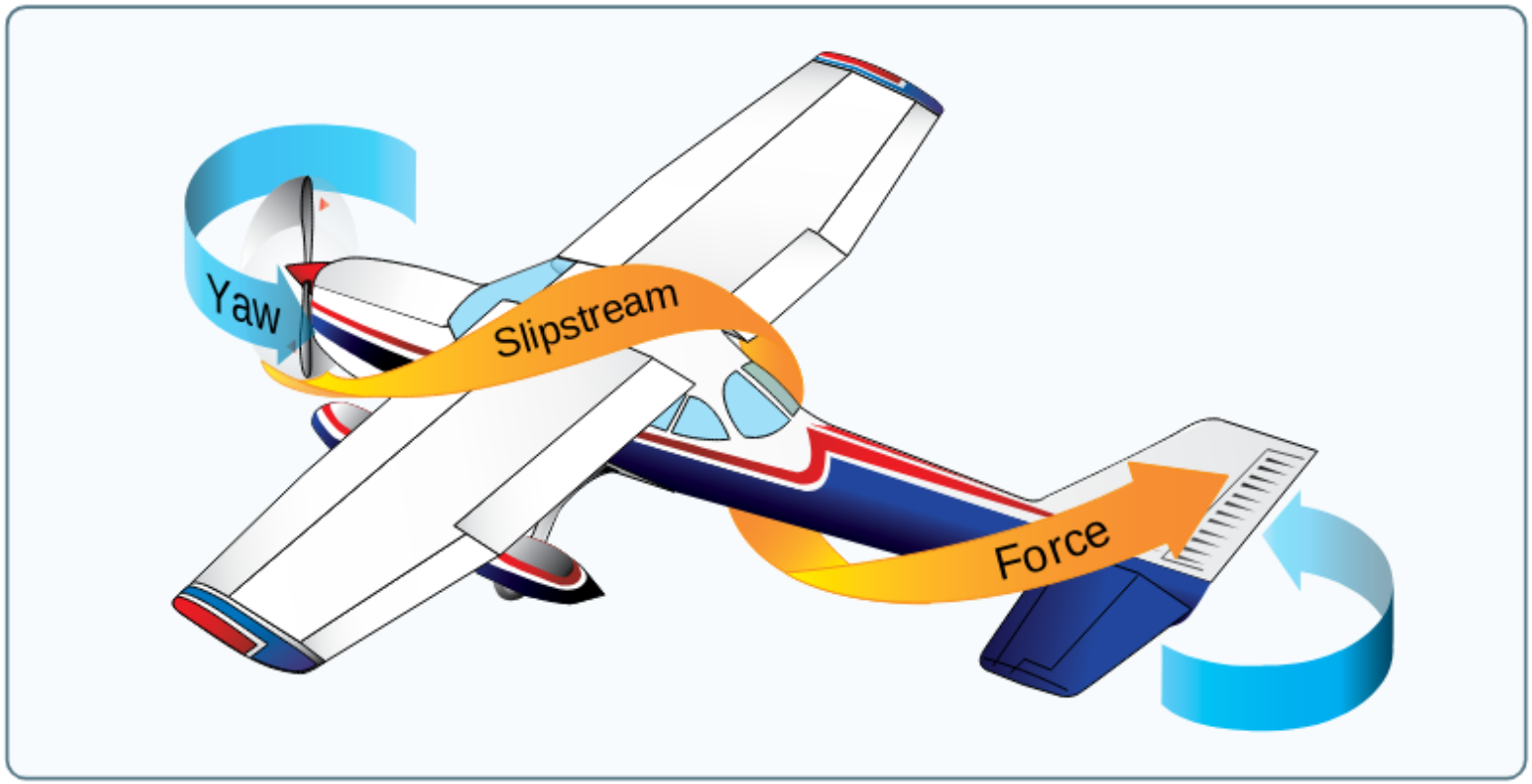
Propeller


Rotational velocity
Thrust
Pitch or blade angle
Angle of attack
Chord line
Forward velocity
Relative wind

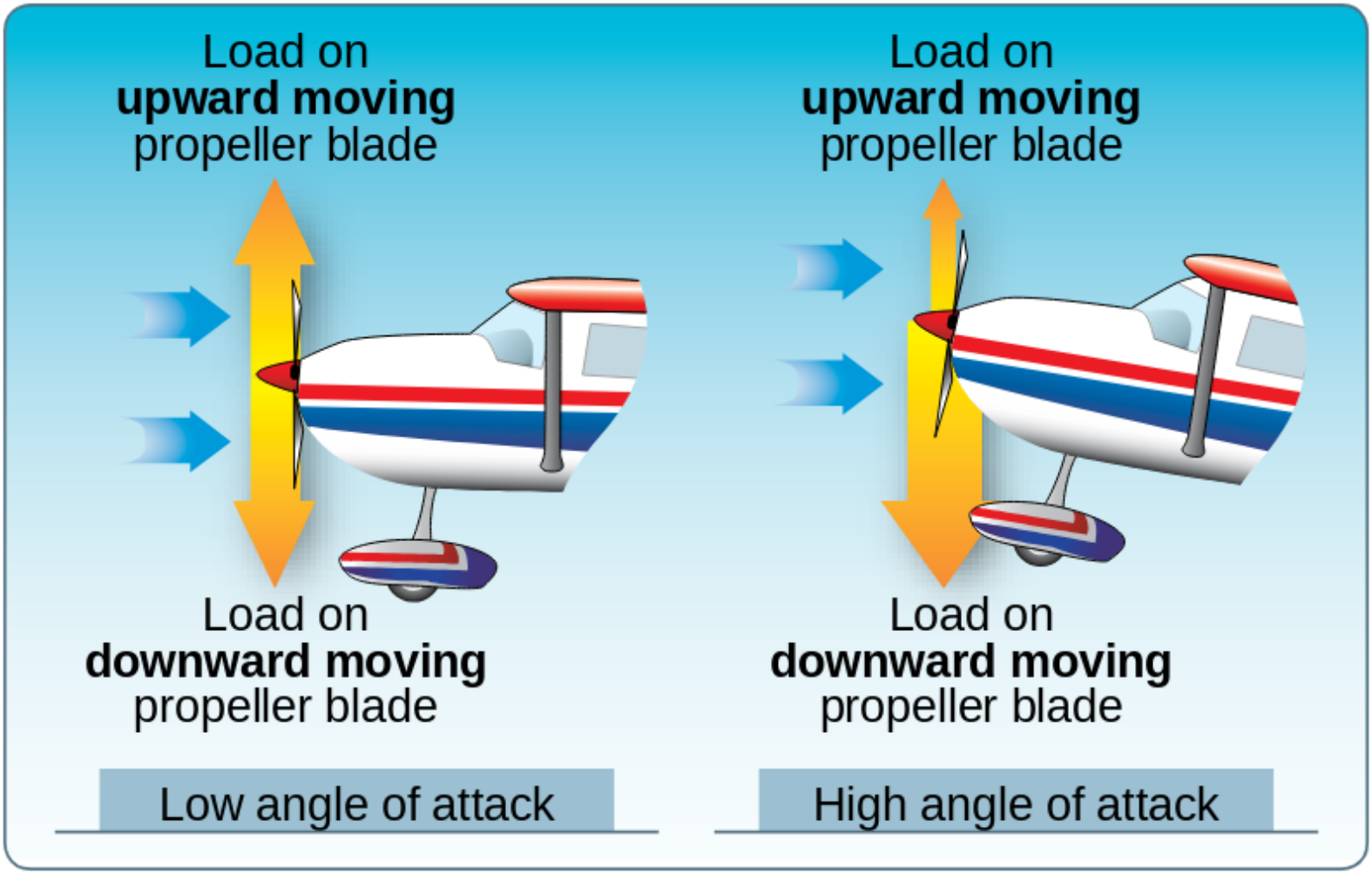
Propeller



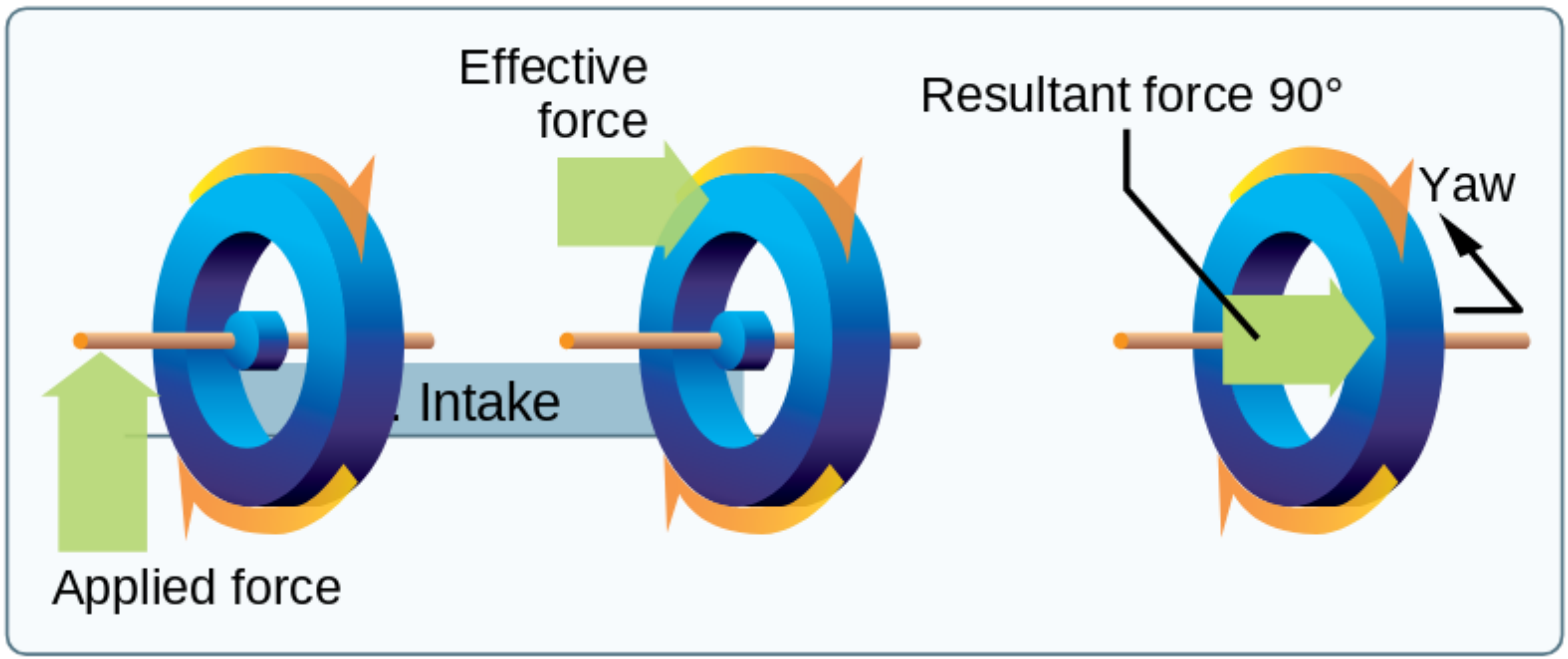
Propeller



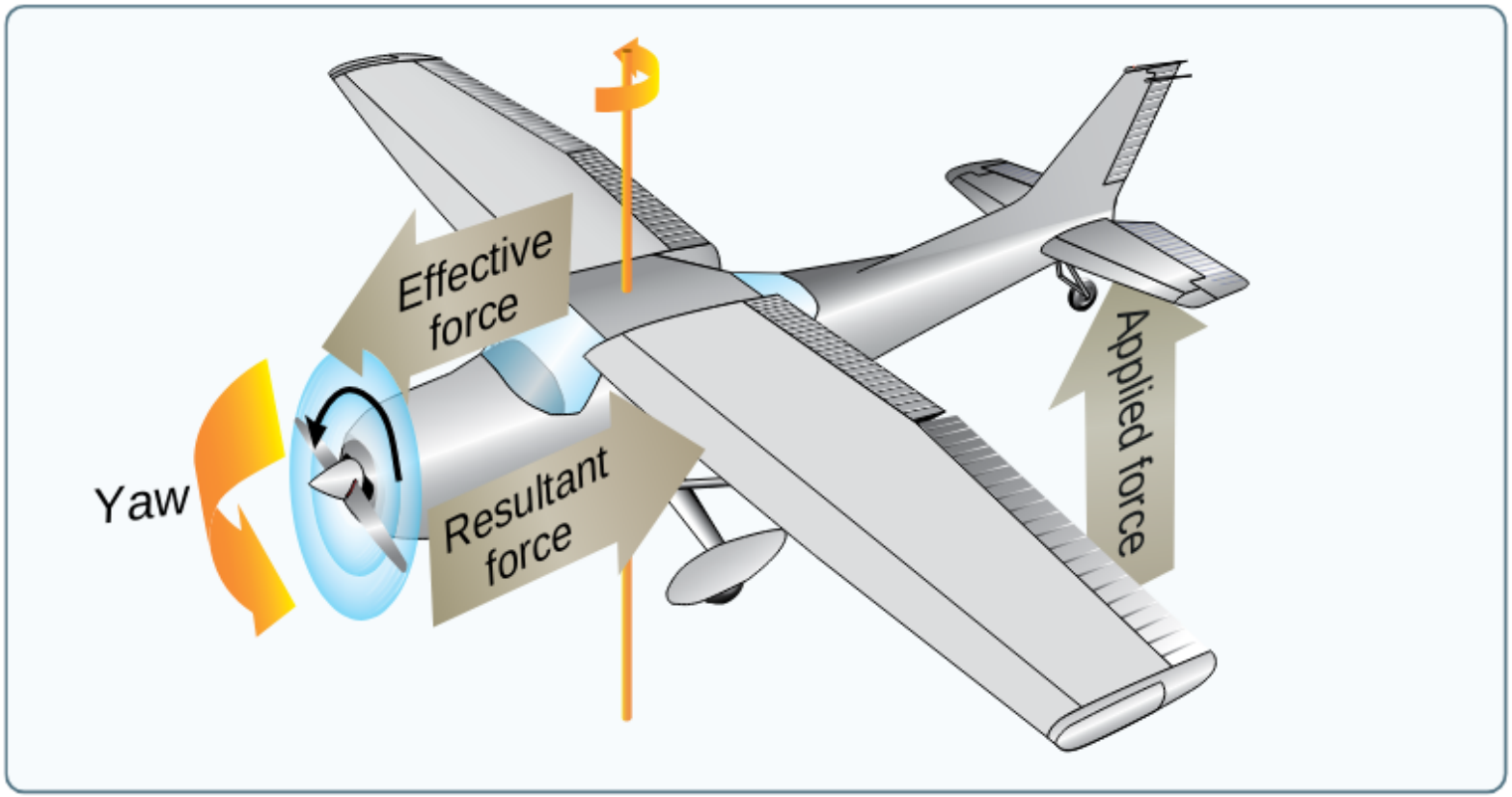
Propeller


Load on
upward moving
propeller blade
Load on
downward moving
propeller blade
Low angle of attack
Load on
upward moving
propeller blade
Load on
downward moving
propeller blade
High angle of attack

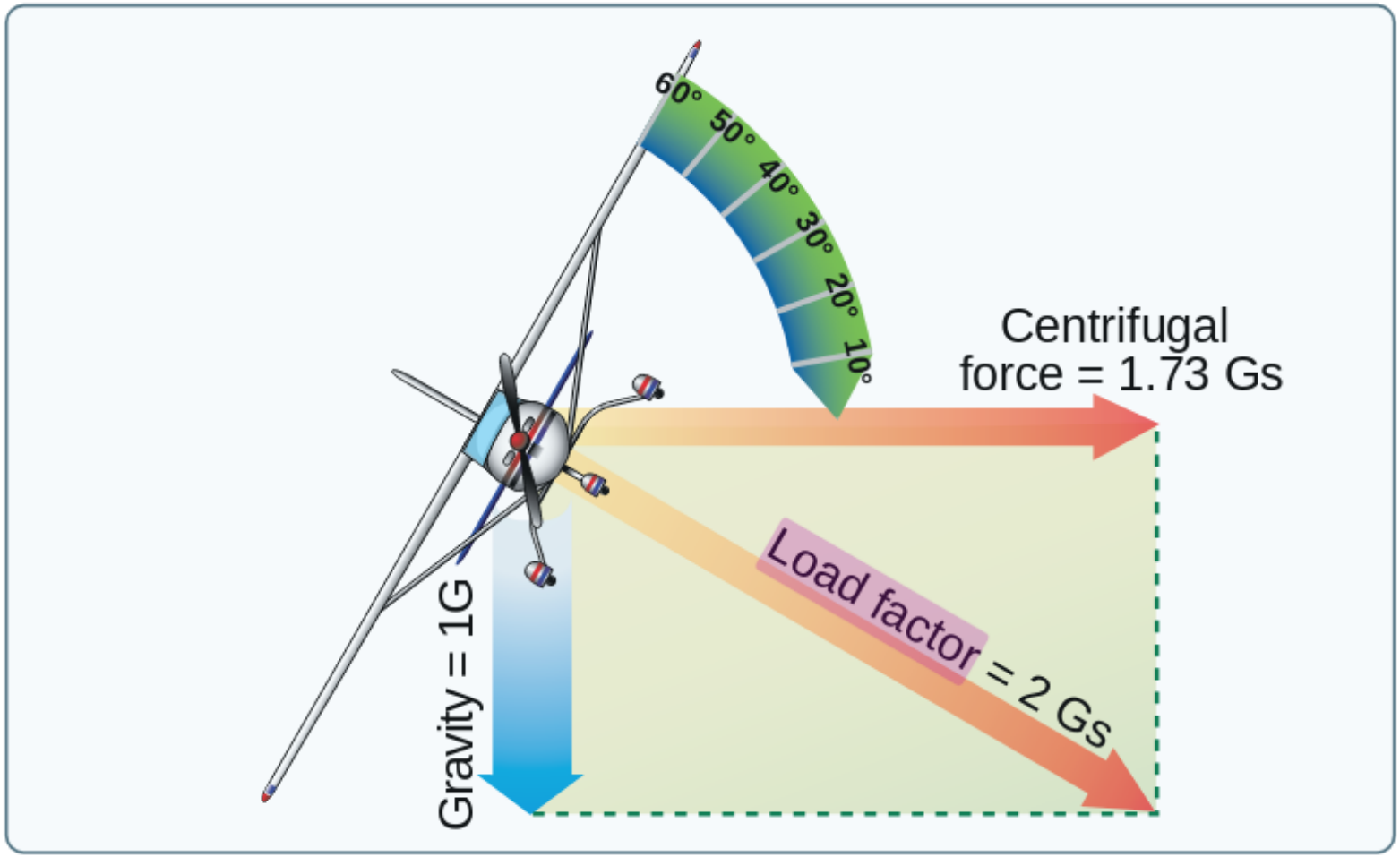
Propeller


Effective
force
Resultant force 90°
Yaw
Intake
Applied force

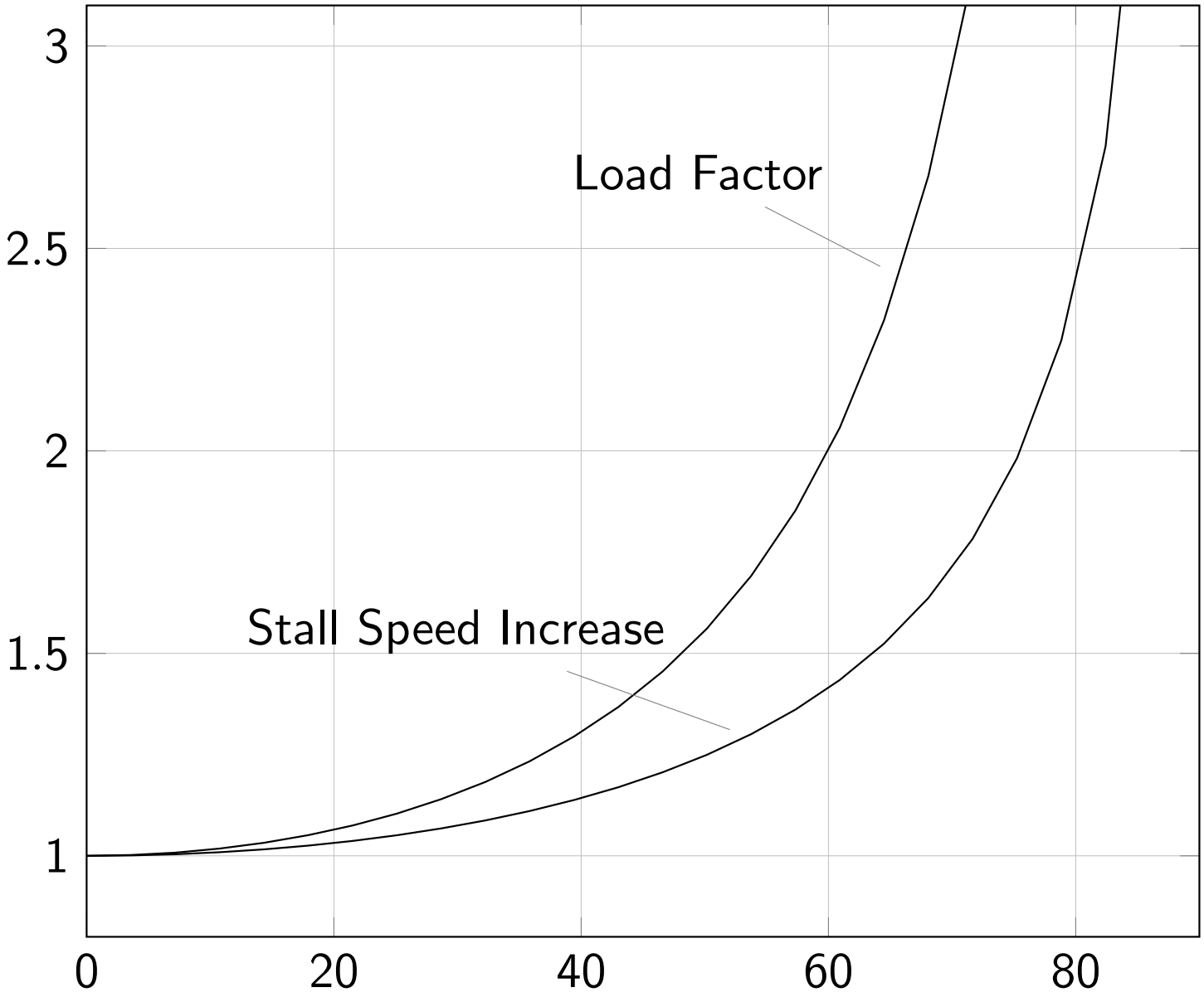
Propeller



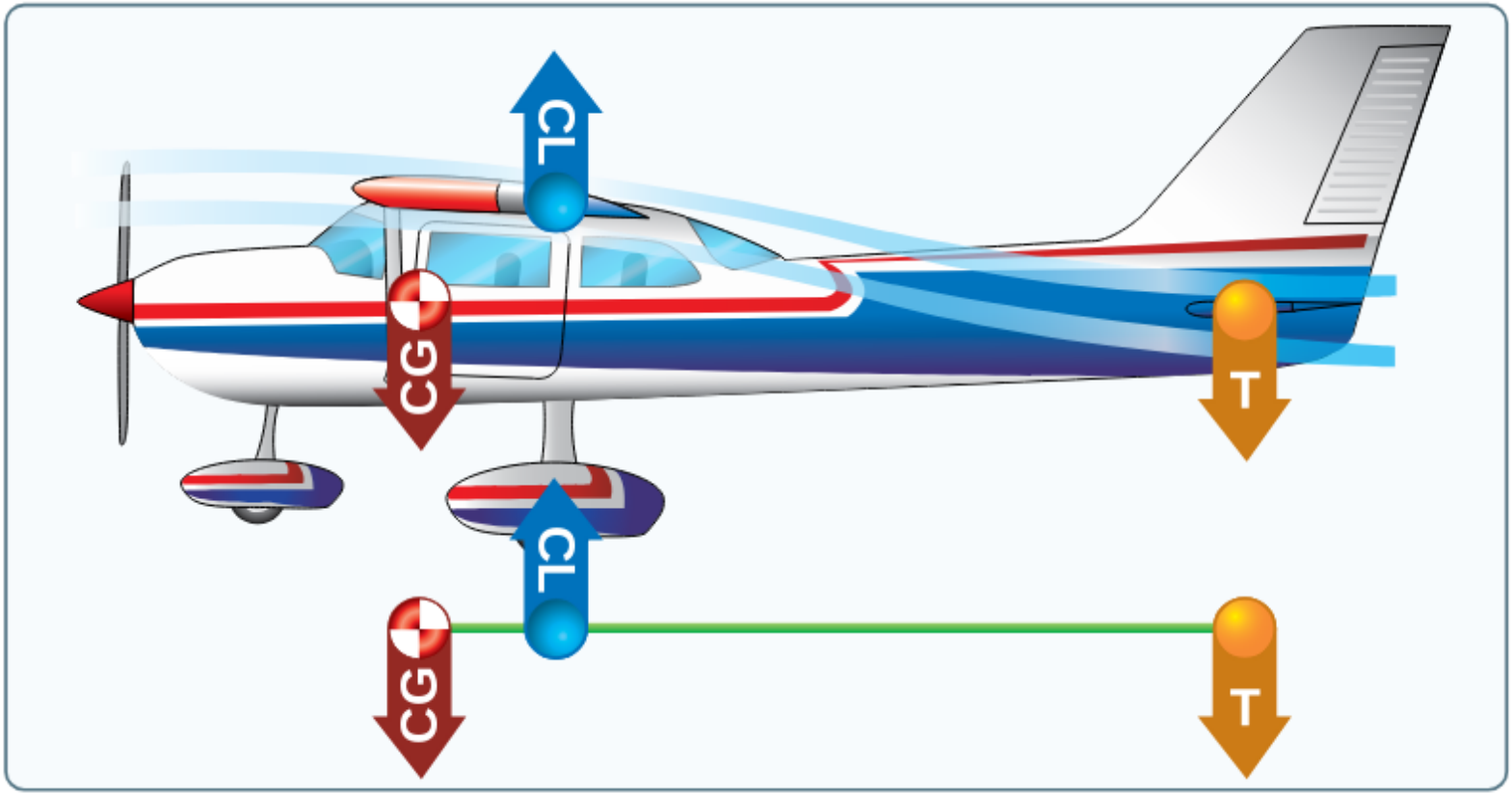
Load Factor


60°
50°
40°
30°
20°
10°
Centrifugal
force = 1.73 Gs
Load factor = 2 Gs
Gravity = 1G

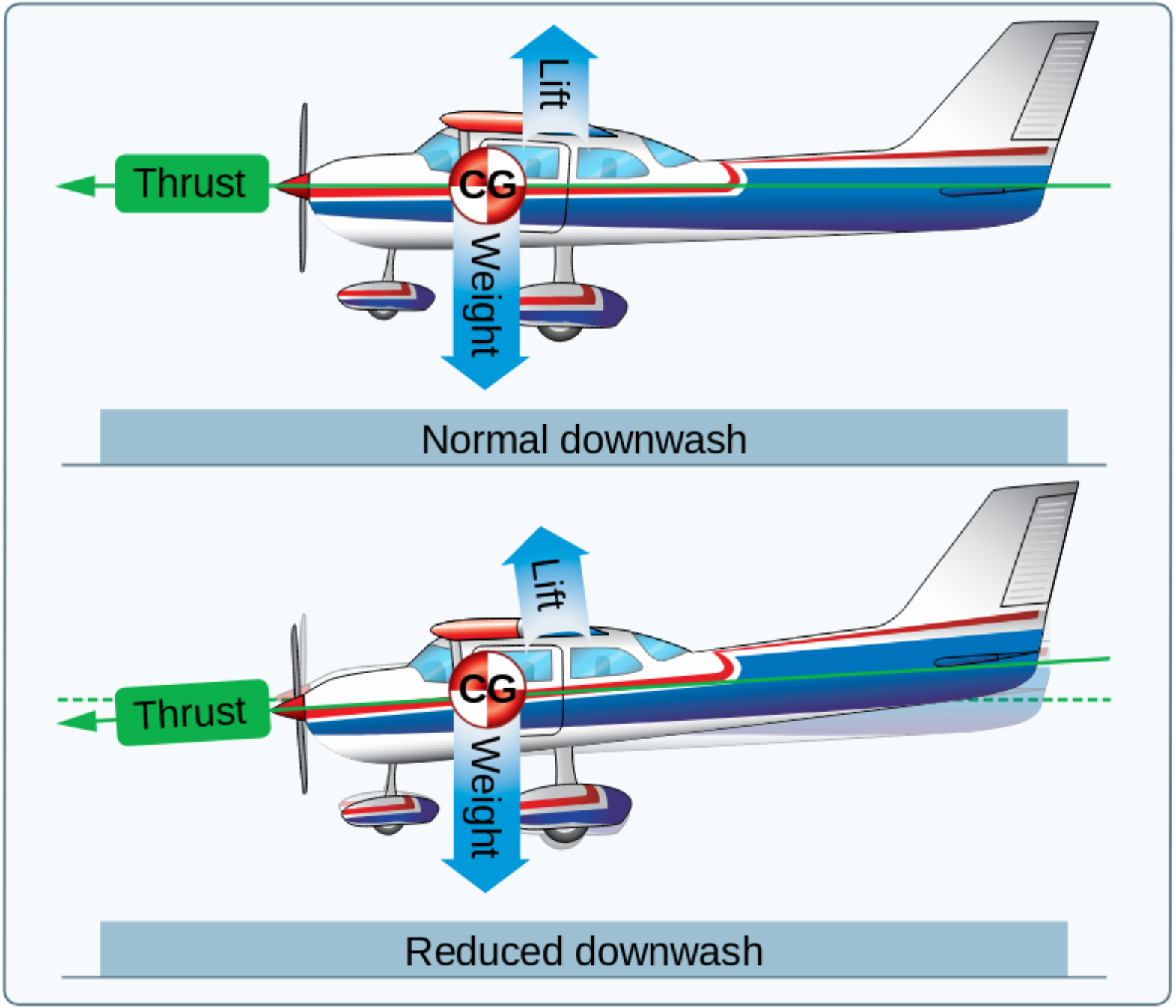
Load Factor and Stall



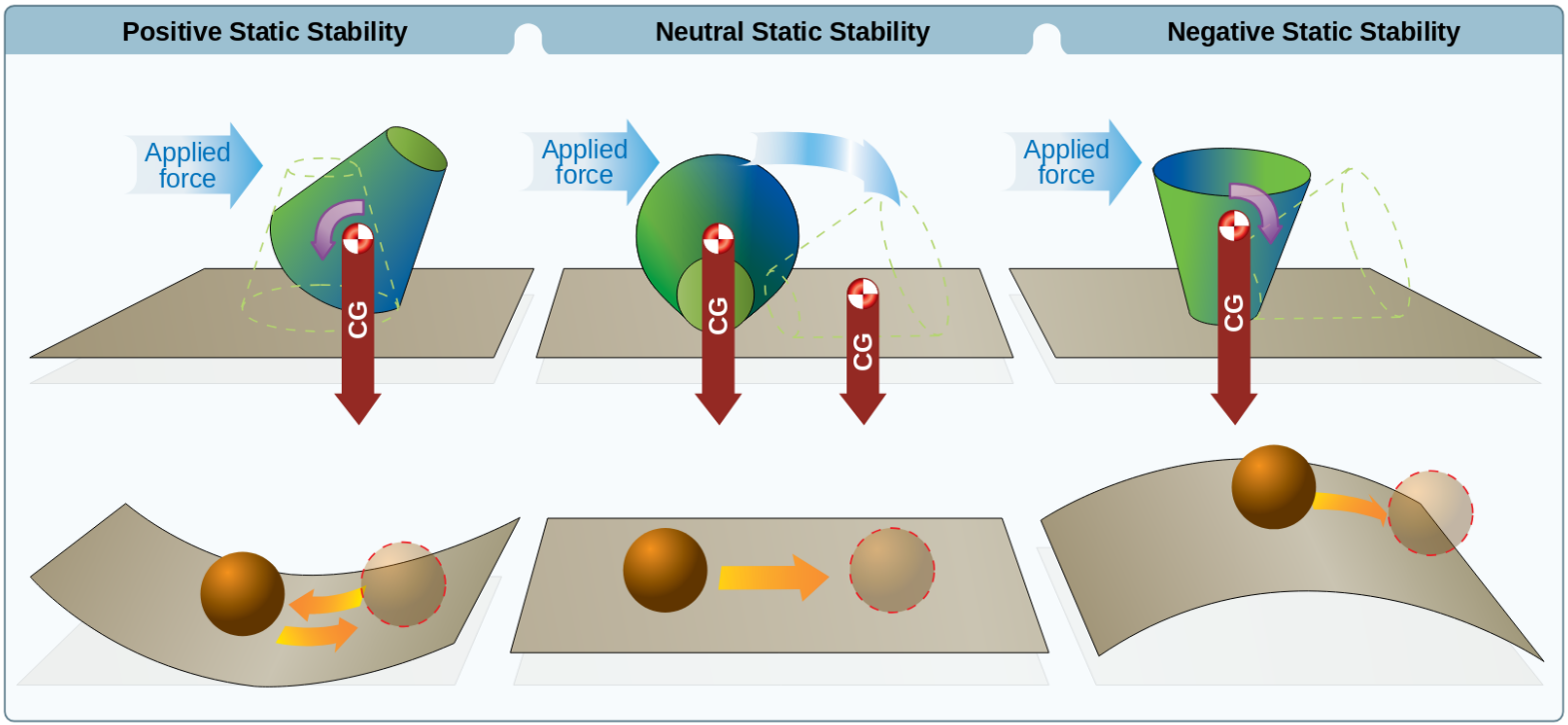
Center of Gravity



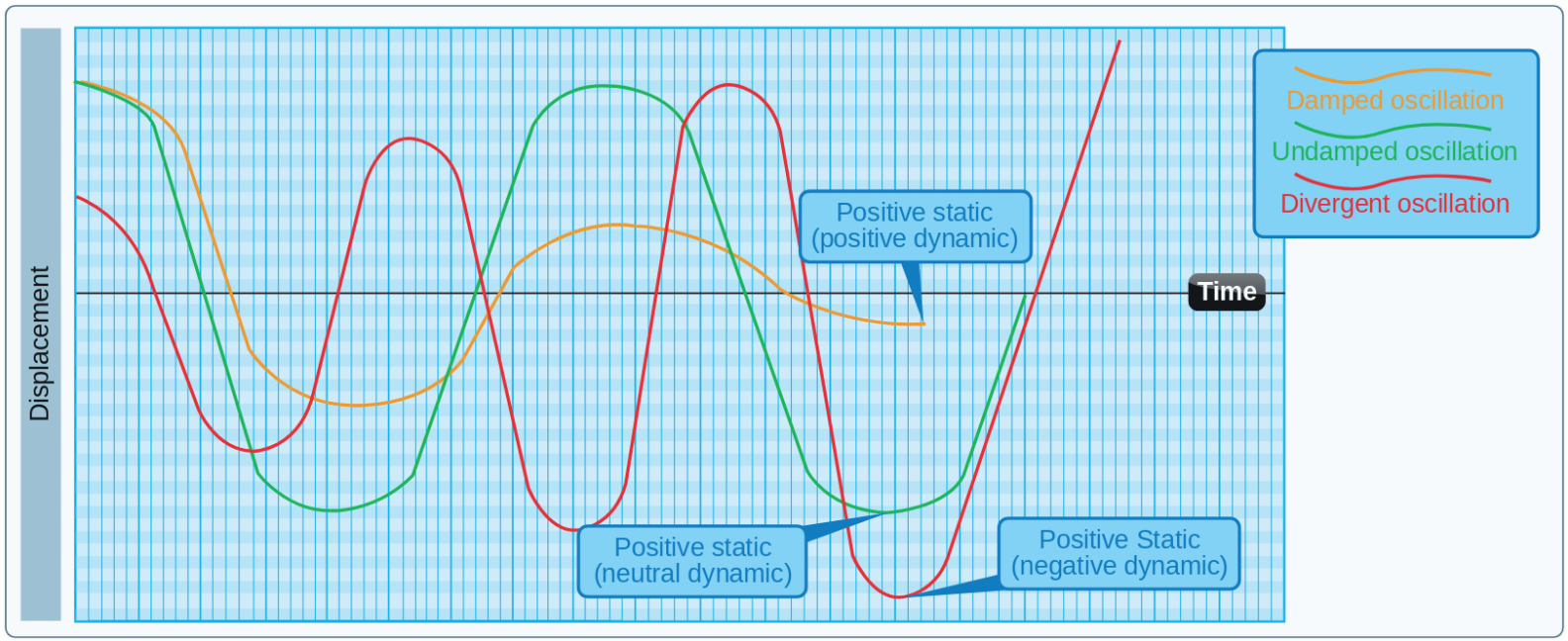
Down Wash


Lift
Thrust
CG
Weight
Normal downwash
Lift
Thrust
CG
Weight
Reduced downwash

Static Stability



Dynamic Stability



1) When are the four aerodynamic forces that act on an airplane in equilibrium?

A When the aircraft is at rest on the ground.

B When the aircraft is accelerating.

C During unaccelerated flight.

2) The purpose of the rudder on an airplane is to

A control the yaw.

B control the overbanking tendency.

C maintain a crab angle to correct drift.

3) The term *angle of attack* is defined as the

A angle between the wing chord line and the relative wind.

B angle between the airplane's climb angle and the horizon.

C angle formed by the longitudinal axis of the airplane and the chord line of the wing.

4) As altitude increases, the indicated airspeed at which a given airplane stalls in a particular configuration will

A decrease as the true airspeed increases.

B decrease as the true airspeed decreases.

C remain the same regardless of altitude.

5) What causes an airplane (except a T-tail) to pitch nosedown when power is reduced and the controls are not adjusted?

A The CG shifts forward when thrust and drag are reduced.

B The downwash on the elevators from the propeller slipstream is reduced and elevator effectiveness is reduced.

C When trust is reduced to less than weight, lift is also reduced and the wings can no longer support the weight.

6) What affect does an increased load factor have on an airplane during an approach to a stall?

A The airplane will stall at a higher airspeed.

B The airplane will have a tendency to spin.

C The airplane will have a tendency to yaw and roll as the stall is encountered.

7) What determines the longitudinal stability of an airplane?

A The location of the CG with respect to the center of lift.

B The effectiveness of the horizontal stabilizer, rudder, and rudder trim tab.

C The relationship of thrust and lift to weight and drag.

8) The left-turning tendency of an airplane caused by P-factor is the result of the

A clockwise rotation of the engine and the propeller turning the airplane counter-clockwise.

B propeller blade descending on the right, producing more thrust than the ascending blade on the left.

C gyroscopic forces applied to the rotating propeller blades acting 90° in advance of the point the force was applied.

9) What is the purpose of wing flaps?

A To enable the pilot to make steeper approaches to a landing without increasing speed.

B To relieve the pilot of maintaining continuous pressure on the controls.

C To decrease wing area to vary the lift.

10 In what flight condition is torque effect the greatest in a single-engine airplane?

A Low airspeed, high power, high angle of attack.

B Low airspeed, low power, low angle of attack.

C High airspeed, high power, high angle of attack.

11) What makes an airplane turn?

A Vertical component of lift.

B Horizontal component of lift.

C Centrifugal force.

12) As you maneuver an airplane you should realize that it can be stalled

A only when the nose is high and the speed is low.

B only when the airspeed decreases to the published stalling speed.

C at any airspeed and in any attitude.

13) To counteract the effect of torque in a conventional, single-engine, propeller-driven airplane, a pilot would normally add

A left rudder pressure during the takeoff roll and while climbing with full power.

B right rudder pressure when entering a glide from level cruising flight.

C right rudder pressure during the takeoff roll and while climbing with full power.

14) To generate the same amount of lift as altitude is increased, an airplane must be flow at

A the same true airspeed regardless of angle of attack

B a lower true airspeed and a greater angle of attack.

C a higher true airspeed for a any given angle of attack.

15) During a spin to the left, which wings are stalled?

A Both wings are stalled.

B Neither wing is stalled.

C Only the left wing is stalled.