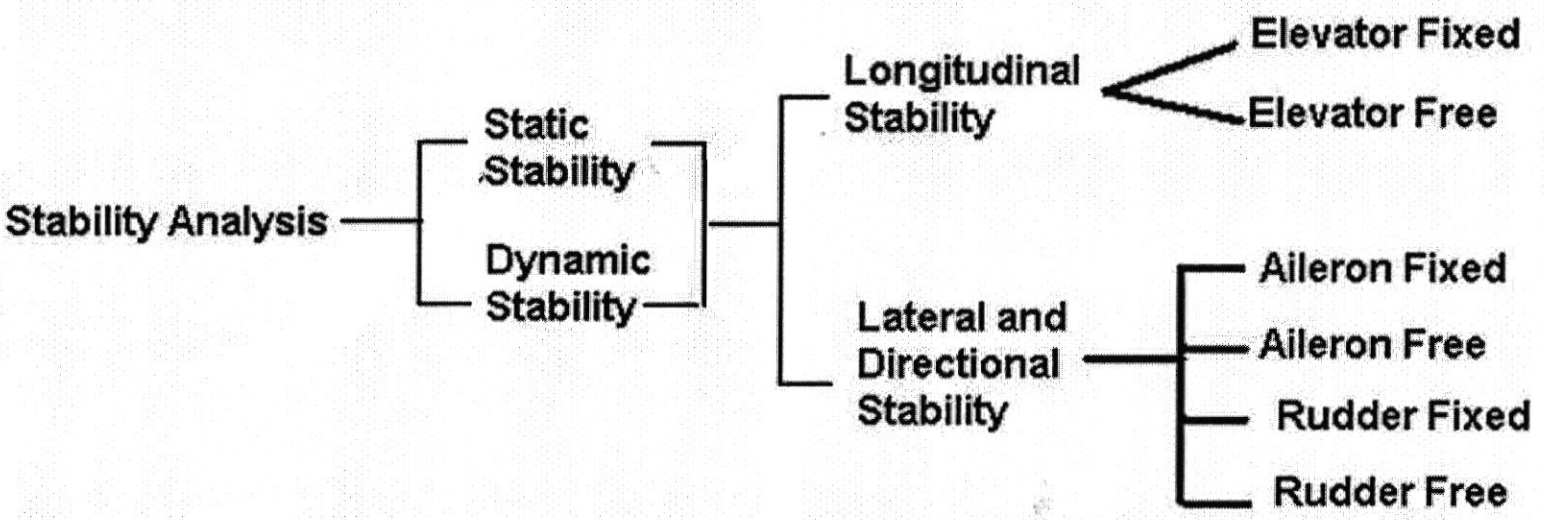
Stability Analysis



Elevator, Aileron & Rudder Fixed ➔ These are at a fixed angle during the motion
Elevator, Aileron & Rudder Free ➔ They are free to adjust as the motion goes on

Equilibrium, Stability and Control

- ***Equilibrium*** : When all forces (Lift, Weight, Drag, Thrust) and moments about the c.g cancel out
- ***Stability*** : An airplane is said to be statically stable if, following a disturbance, forces and moments are produced by the airplane which tend to reduce the disturbance by itself.
- ***Control*** : Forces and moments produced by pilot inputs to bring the airplane back to equilibrium after disturbance.

Equilibrium, Stability and Control

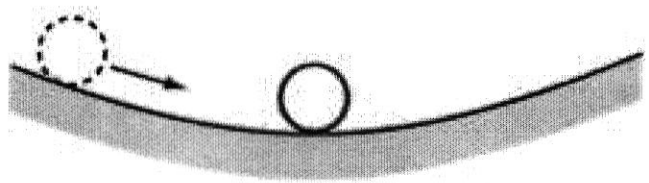
- Stability and controllability are different
  - Stability : If a system is in equilibrium, ability to maintain that state
  - Controllability : the ability to change the equilibrium state
- Very stable airplane will resist changes in it's attitude and hence, will be difficult to control.
- Military airplanes, for which maneuverability is one of the requirements, have lower levels of stability than civil airplanes.
- Stability is desirable but not necessary in piloted planes

Stability

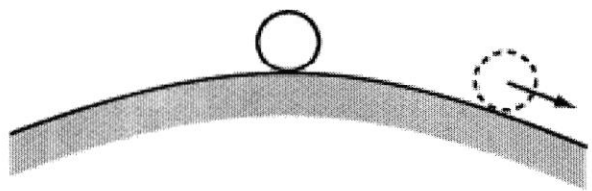
- An airplane may be stable under some conditions of flight and unstable under other conditions.
- For instance, an airplane which is stable during straight and level flight may be unstable when inverted, and vice versa.
  - This stability is sometimes called inherent stability.
- Modern combat aircraft are deliberately made to be inherently unstable, as this increases their manoeuvrability (Eg TEJAS)
- This requires a sophisticated automatic artificial stabilisation system, which has to be totally reliable.

Static Stability – 1 DOF

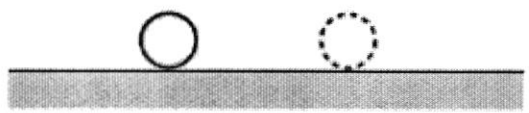
Statically stable. If the forces and moments on the body caused by a disturbance tend initially to return the body toward its equilibrium position, the body is ***statically stable***.



Statically unstable. If the forces and moments are such that the body continues to move away from its equilibrium position after being disturbed, the body is ***statically unstable***.

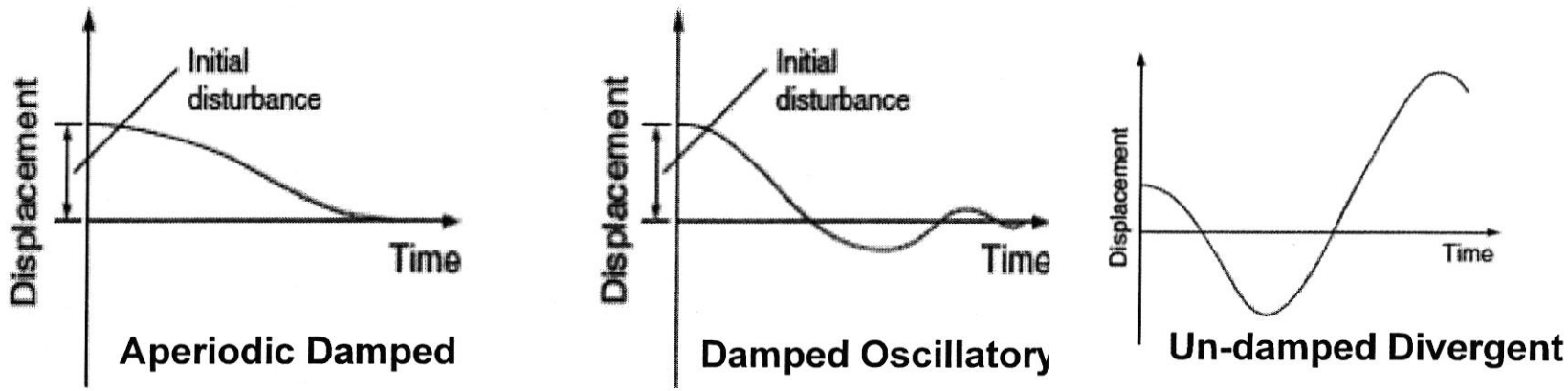


Neutrally stable. If the body is disturbed but the moments remain zero, the body stays in equilibrium and is ***neutrally stable***



Dynamic Stability

1. ***Dynamic stability*** deals with the time history of the vehicle's motion after it initially responds to its static stability.
2. Consider an airplane flying at an angle of attack (AOA) such that the moments about the center of gravity (cg) are zero.
3. The aircraft is therefore in equilibrium at α_e and is said to be trimmed, and α_e is called the trim angle of attack.
4. Now imagine that a wind gust disturbs the airplane and changes its angle of attack to some new value α . Hence, the plane was pitched through a displacement ($\alpha - \alpha_e$)
5. Three responses are possible



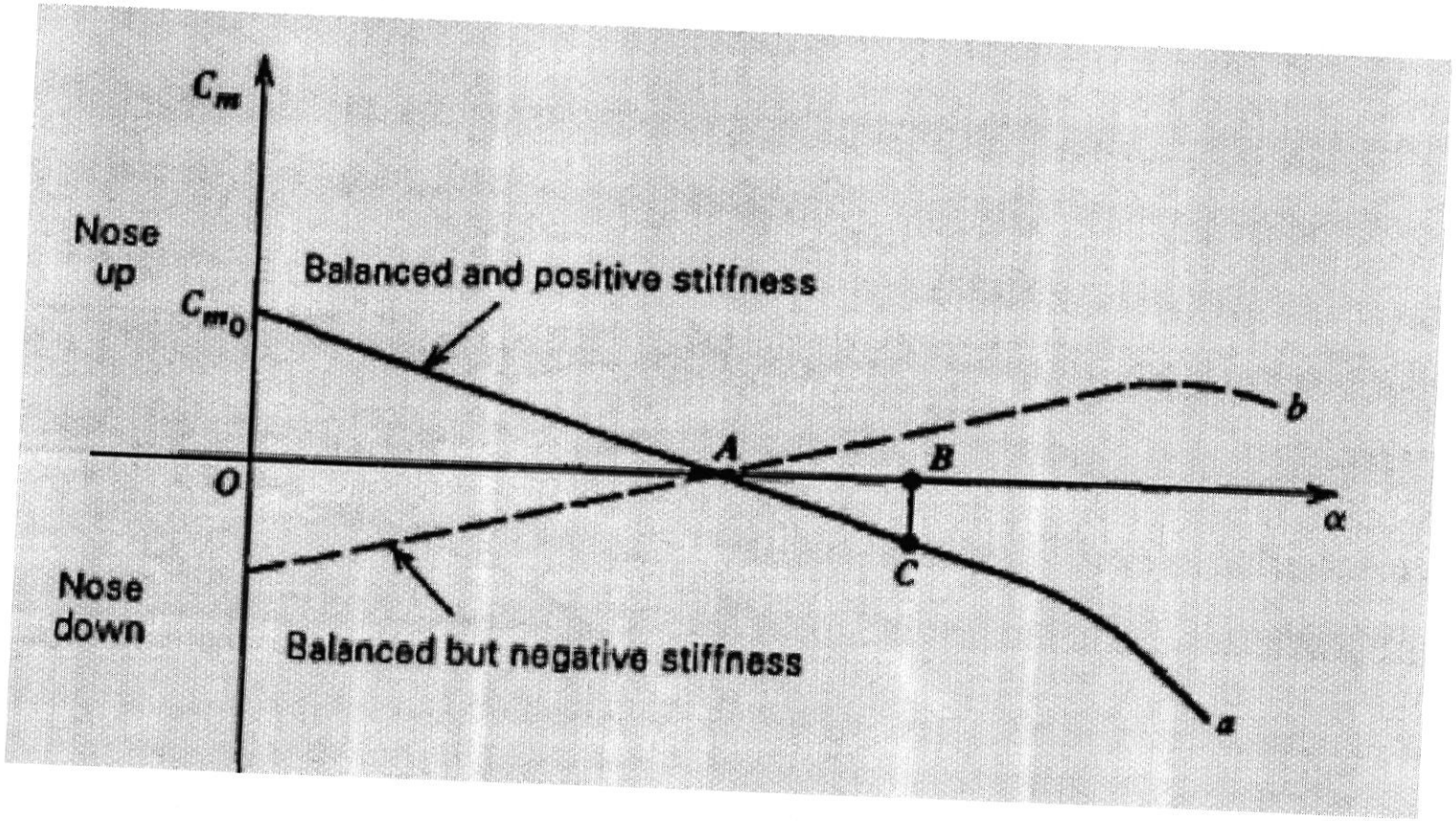
Stability

- For a successful flight :
  - Airplane must be able to achieve equilibrium flight
  - It must be manoeuvrable for wide range of velocities and altitudes
- For these, aircraft must possess aerodynamic and propulsive controls
- Stability and control characteristics of an airplane are referred to as handling characteristics

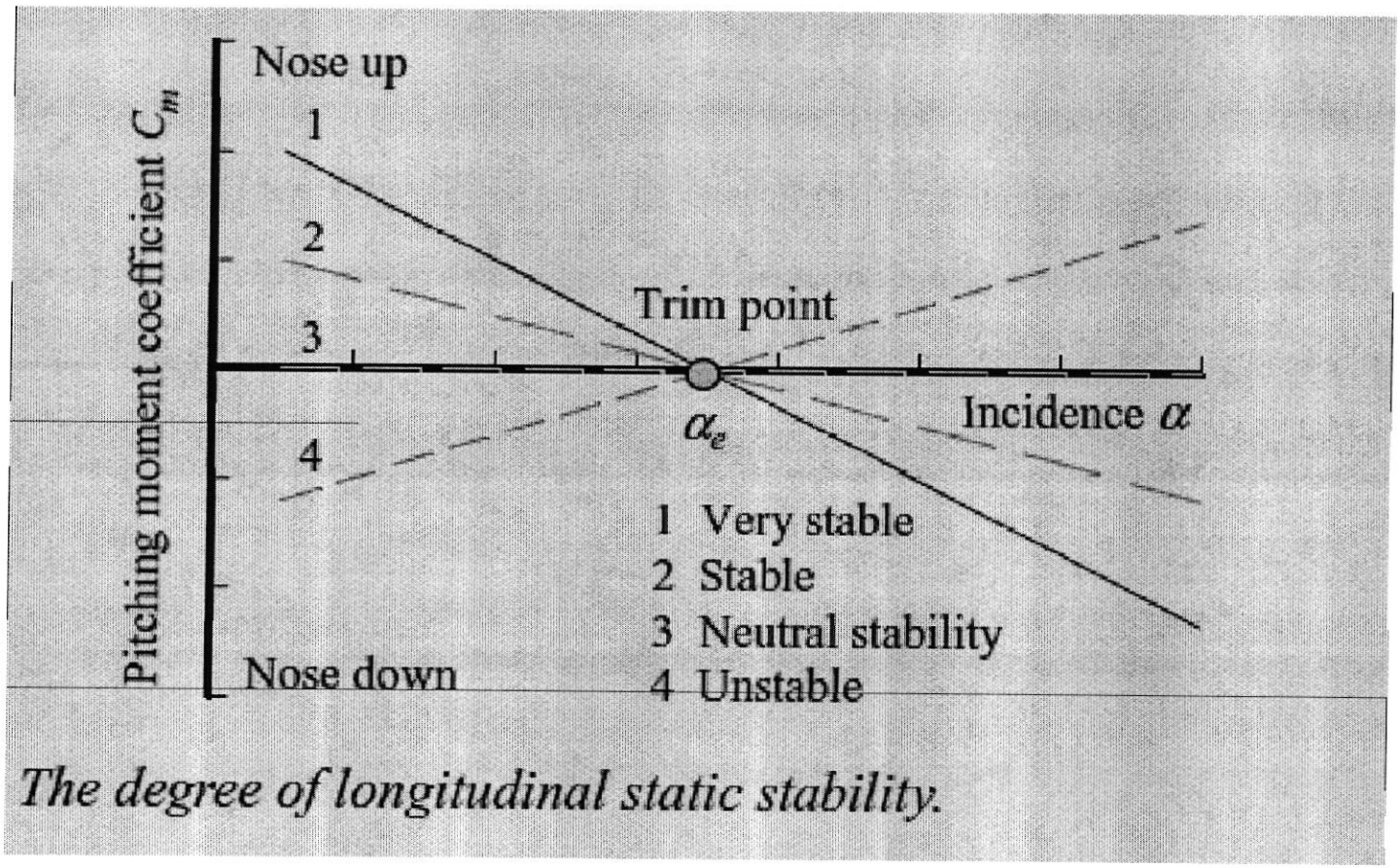
Longitudinal Stability and Control

- Wing Contribution
- Aft Tail Contribution
- Canard Configuration
- Fuselage Contribution
- Power Effects
- Elevator Effectiveness
- Elevator Trim
- Hinge Moment

Pitching Moment Vs CL

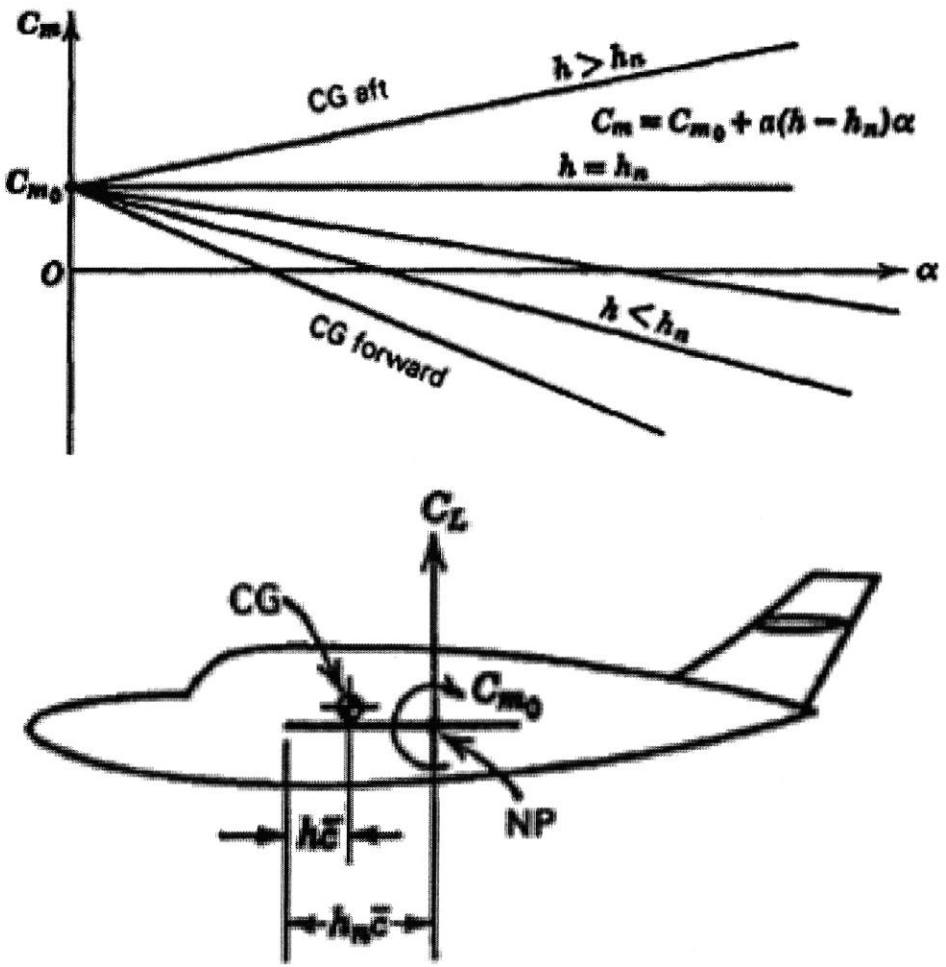


Degree of Longitudinal Stability



The degree of longitudinal static stability.

Effect of CG movement



Directional Stability and Control

- Following components contribute to instability
  - Wing Contribution
  - Fuselage Contribution
  - Nacells
- Following components contribute to instability
  - Vertical Tail Contribution
  - Rudder

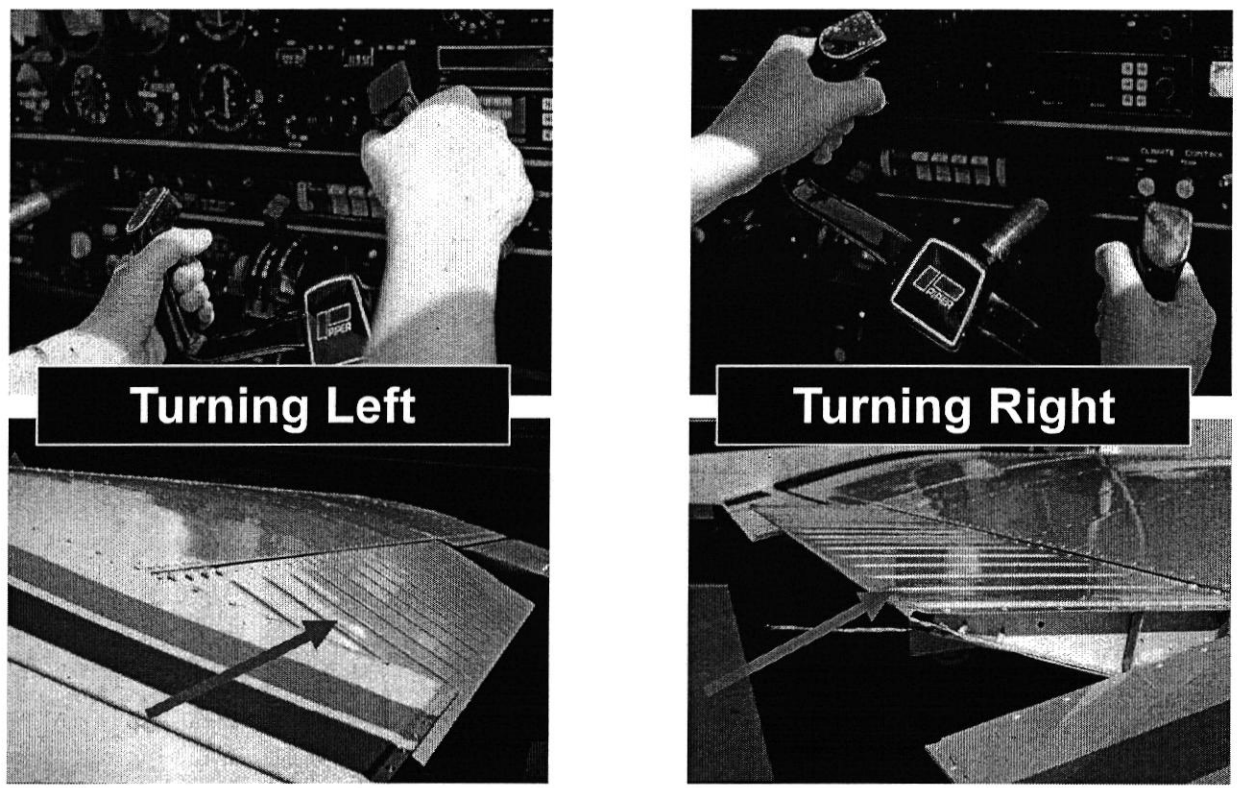
Roll Stability and Control

- Wing Dihedral
- Wing Sweep
- Position of Wings on Fuselage
- Vertical Tail
- Ailerons
- Spoiler

FLIGHT CONTROLS

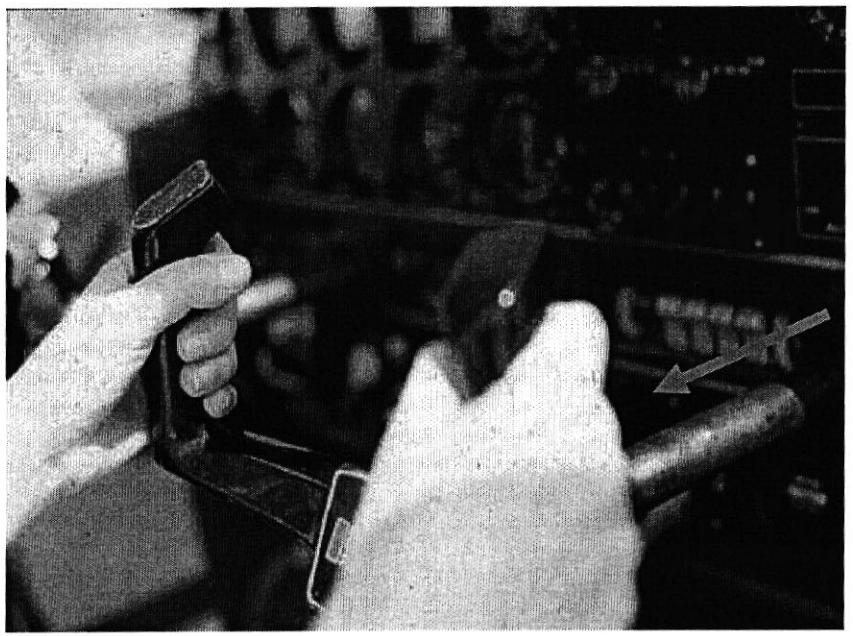
Flight controls and instrument panels vary, but have the same basic functions.

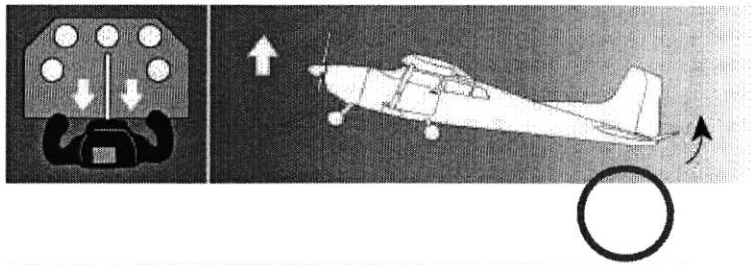
FLIGHT CONTROLS

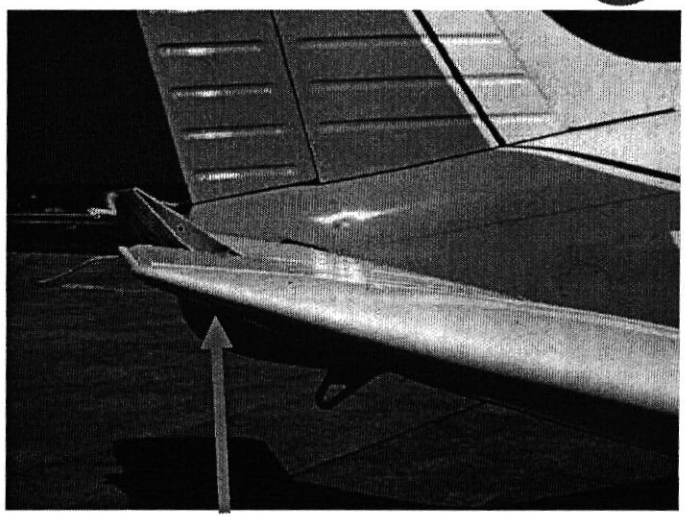


Moving the yoke LEFT or RIGHT moves the ailerons on the wings in opposite directions. One moves UP as the other goes DOWN.

FLIGHT CONTROLS







Pulling back on the yoke moves the elevator on the tail UP, moving the airplane nose UP to climb.