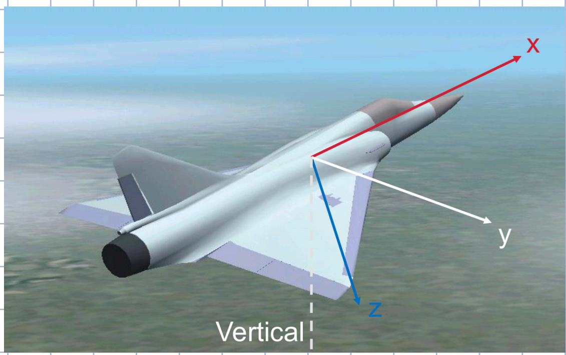
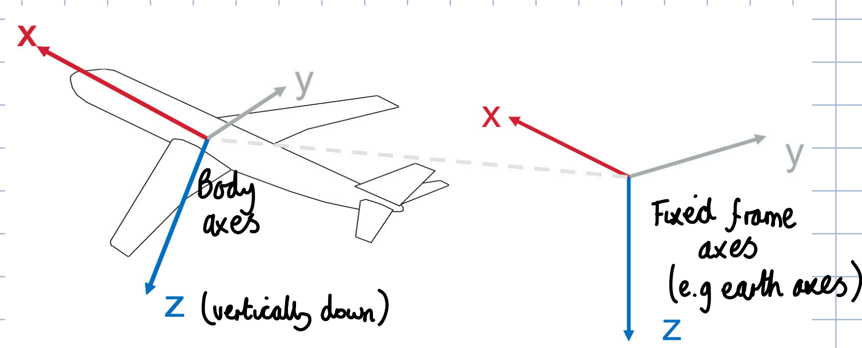
Body Axes :



Rigid bodies with a distributed mass require a local set of axes attatched to the body, with a second set for reference.



Movements of a point mass do not require local set of axes attatched to mass.

There are 6 motions of a rigid body - 3 translational, 3 rotational

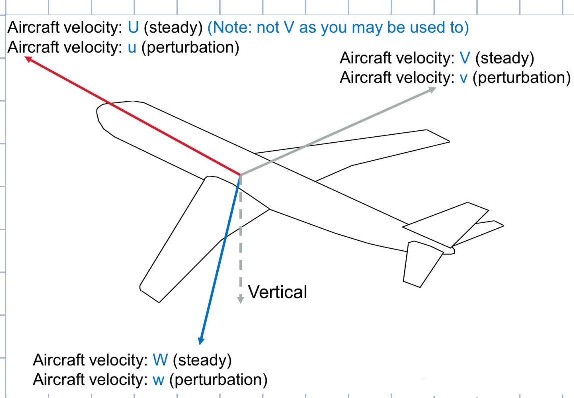
→ motions are measured relative to reference set of axes → relative motion to where local axes started.

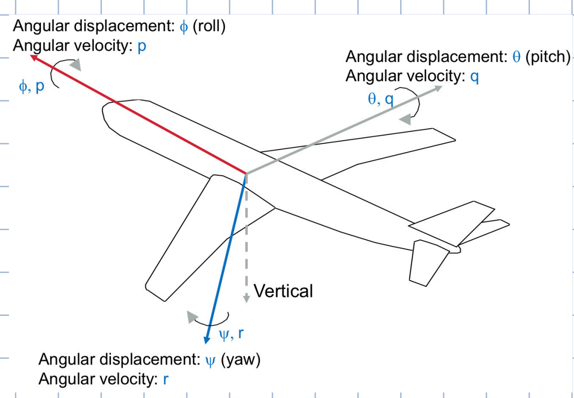
Body axes origin fixed to some easily defined point → CG could be used but may vary throughout flight so not often used

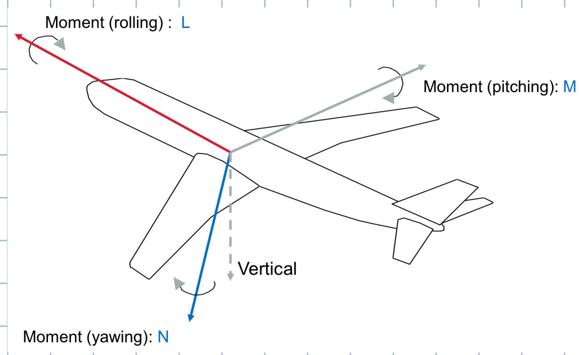
Body Axes Notation & Sign Conventions :

x	→	y	→	z
roll*	→	pitch	→	yaw
u	→	v	→	w
ϕ	→	θ	→	ψ

*about axis above

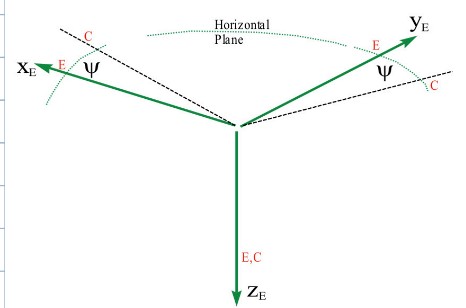




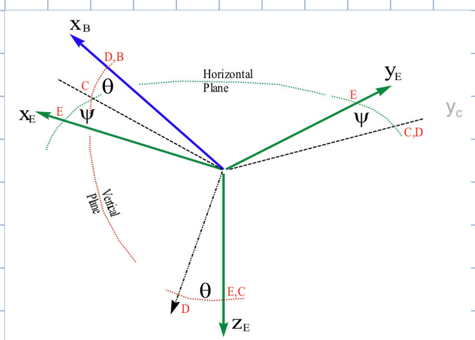


Euler Angles: to go from earth axes frame, $F_E \rightarrow$ body axes frame, F_B (via two intermidiate frames F_C & F_D)

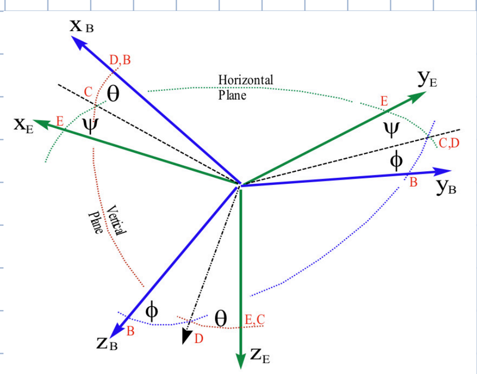
1. Rotation ψ about z_E to intermediate frame F_C



2. Rotation θ about y_C to intermediate frame F_D



3. Rotation ϕ about x_D to body axes frame F_B



Wind Axes :

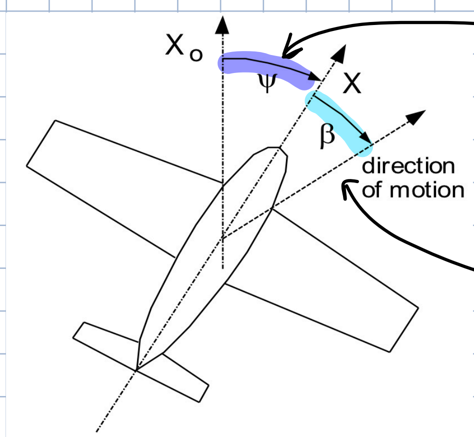
- Orientation of the wind axes usually chosen for convenience of defining aerodynamic forces.
- Origin is fixed at the aircraft reference point
- X-axis points into the wind

Aerodynamic Incidence Angles : α and β

Sideslip angle

- These incidence angles form the basis of aerodynamic forces
- ψ is not included

ψ & β are not the same :



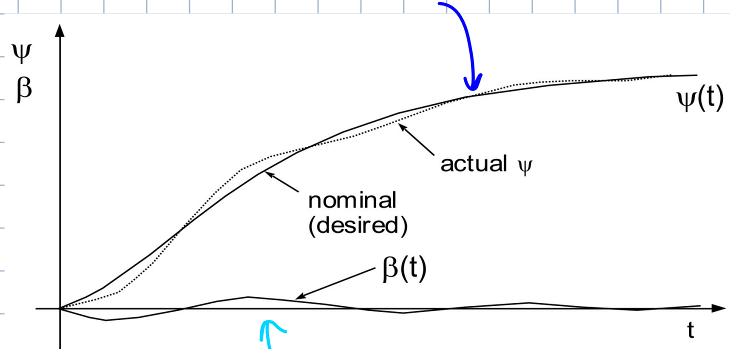
ψ is essentially orientation angle → pointing direction of fuselage reference line compared with previous direction

β is difference between direction of motion & pointing direction

'skidding' to right = +ve sideslip

Sideslip incidence $\boxed{\beta = \frac{V}{U}}$

ψ tends to new steady +ve values



Small yawing oscillations will causes $\psi(t)$ & $\beta(t)$ to be quite seperate functions

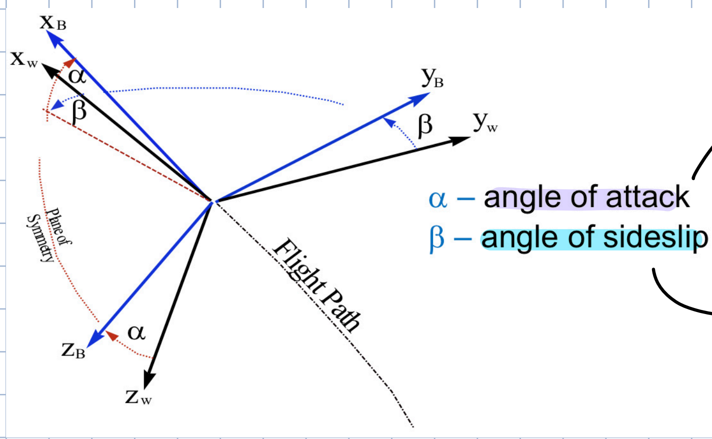
$\beta(t)$ can be ≈ 0 throughout

$\beta(t) = 0$ = coordinated turn

- If atmosphere steady wrt Earth, wind axes are tangent to flight trajectory of aircraft relative to Earth.

- z-wind axis remains in aircraft plane of symmetry although it may tilt forward.

- Only pitch & yaw departures of wind vector are necessary to define wind-induced forces



angle between x_B axis and the plane containing the y_B axis and the velocity vector

angle between velocity vector and plane of symmetry $(x_B z_B)$

State Vector : defines where aircraft is & what it's doing

Can use overall resultant velocity, V_T

$$\dot{V}_T = \frac{U\dot{U} + V\dot{V} + W\dot{W}}{V_T}$$

We can also write

$$\dot{\alpha} = \frac{U\dot{W} - W\dot{U}}{U^2 + W^2} \quad \text{and} \quad \dot{\beta} = \frac{\dot{V}V_T - V\dot{V}_T}{V_T^2 \cos\beta}$$

The state vector is therefore :

$$\boxed{X^T = [V_T \;\; \beta \;\; \alpha \;\; \phi \;\; \theta \;\; \psi \;\; P \;\; Q \;\; R \;\; p_N \;\; p_E \;\; h]}$$

Stability Axes : (not used in depth on this course)

↳ refer to slides if needed.