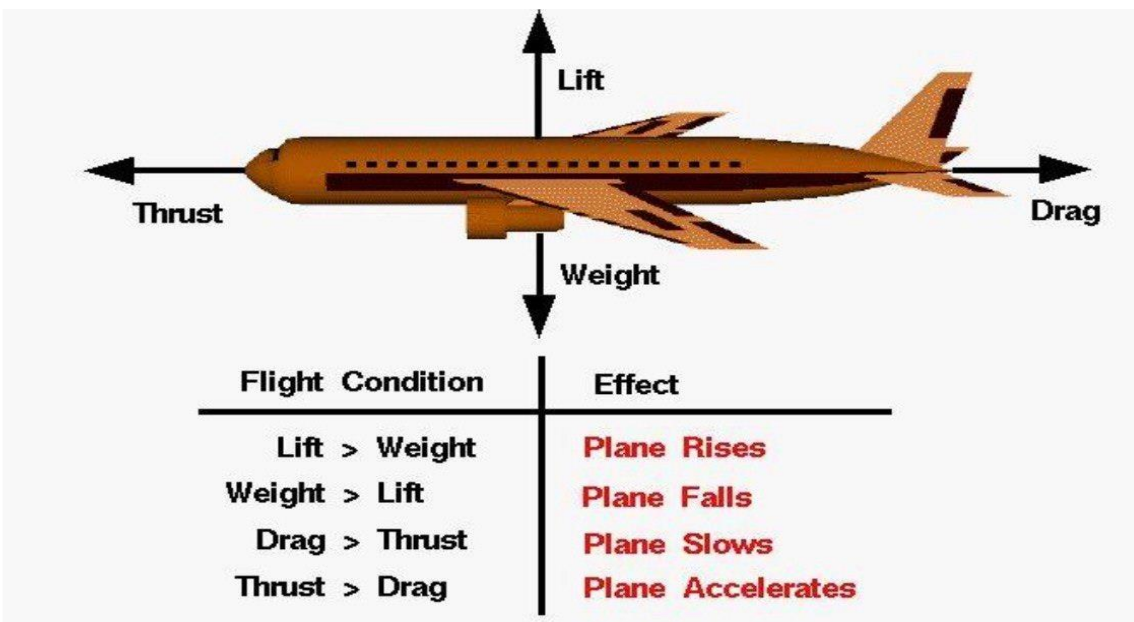
(Statics Forces, moments and couples, representation as vectors; Centre of gravity)

1. Introduction to Engineering Statics

Statics is the branch of engineering mechanics that deals with bodies at rest or in a state of constant velocity (zero acceleration). In aerospace engineering, statics is the foundation for structural analysis, ensuring that components like the fuselage, wings, and landing gear can support loads without failure.



Learning Objectives (CLOs):

1. Understand the vector nature of forces in aircraft structures.

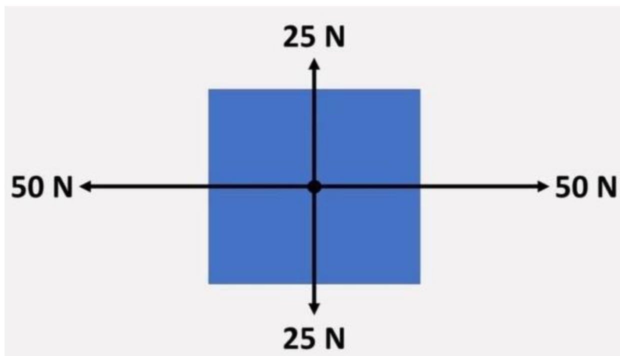
2. Apply Newton's First Law to aerospace components.

3. Calculate moments and centers of gravity for weight and balance.

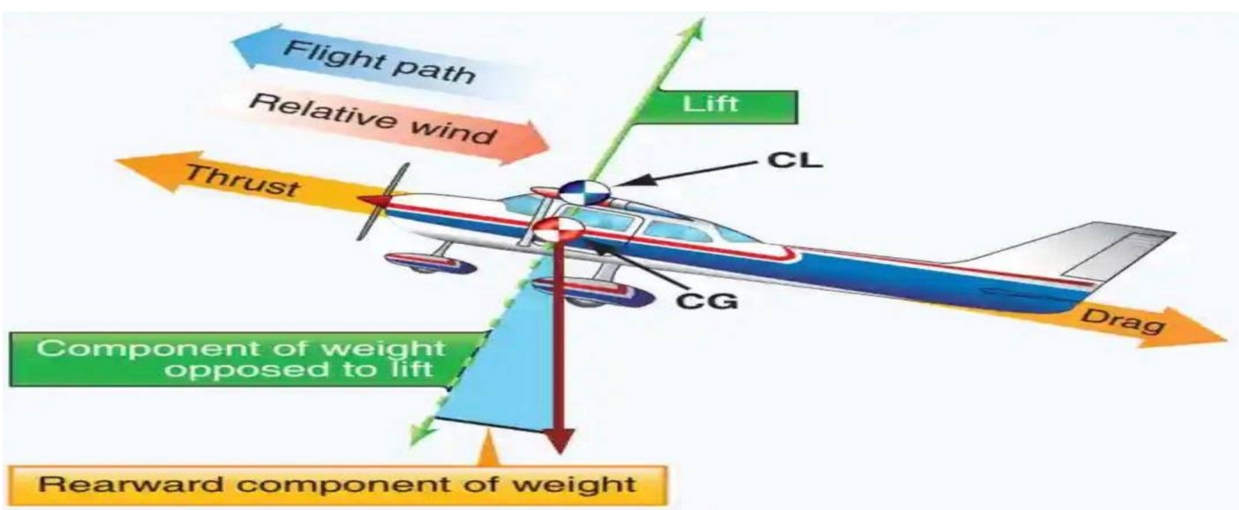
Sameer.Saad.Raheem@uomus.edu.iq

2. Force and Newton's First Law

According to Newton's First Law, a body remains at rest or in steady motion unless acted upon by a resultant force. In statics, the equilibrium condition is defined as:



Sum of Forces (ΣF) = 0



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Example 1: Aircraft in Steady Flight

An aircraft is cruising at a constant velocity. If the engine produces a Thrust (T) of 60,000 N, find the Drag (D) acting on the airframe for equilibrium.

• Solution:

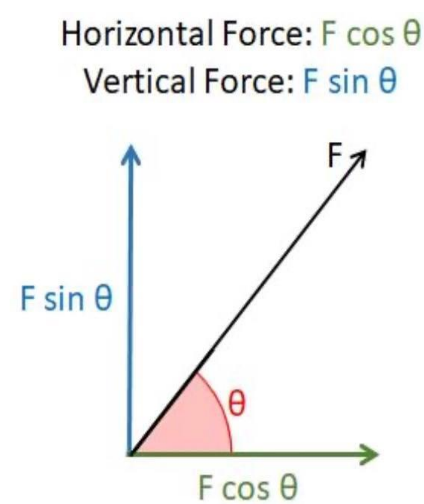
Applying $\Sigma F_x = 0$:

$T - D = 0 \longrightarrow D = 60{,}000$ Newton

(The Drag force is exactly equal to the Thrust in unaccelerated flight).

3. Resolution of Forces (Vector Components)

Forces in aircraft (such as lift on a swept wing) act at various angles. We resolve these into Cartesian components (x, y):



• $F_x = F \cdot \cos(\theta)$

• $F_y = F \cdot \sin(\theta)$

❖ Vector Representation in Cartesian Form:

A force can also be written in vector form as:

F = Fx i + Fy j

Where:

i → unit vector in x-direction

j → unit vector in y-direction

Example 2: Tension in a Tie-down Cable

An aircraft is secured on a carrier deck. A cable exerts a force F = 2500 N at an angle of 30° to the horizontal. Calculate the horizontal and vertical components.

• Solution:

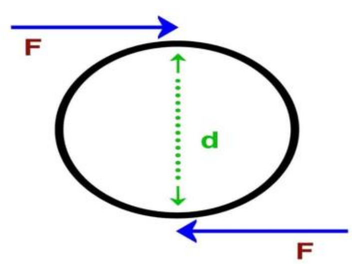
• Fx = 2500 . cos(30°) = 2500 . 0.866 = 2165 N (Horizontal tension)

• Fy = 2500 . sin(30°) = 2500 . 0.5 = 1250 N (Vertical component)

4. Moment of Force and Couples

A Moment (M) is the rotational effect of a force about a specific point or axis.

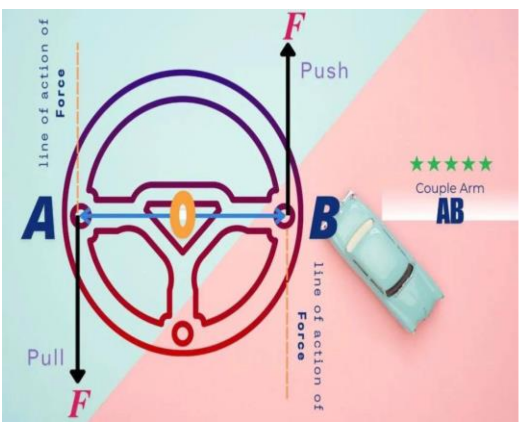
M = F . d (Where d is the perpendicular distance).

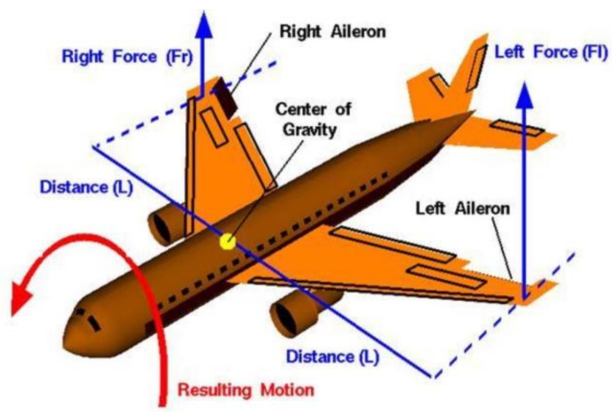


A Couple consists of two equal and opposite forces that produce pure rotation (e.g., the action of ailerons on a wing).

- Important Note: The perpendicular distance (d) is always measured from the line of action of the force to the pivot point.

Engineering Example: A common example of a couple is the rotation of a steering wheel or aircraft ailerons, where equal and opposite forces create pure rotational motion.





Example 3: Rudder Control Moment

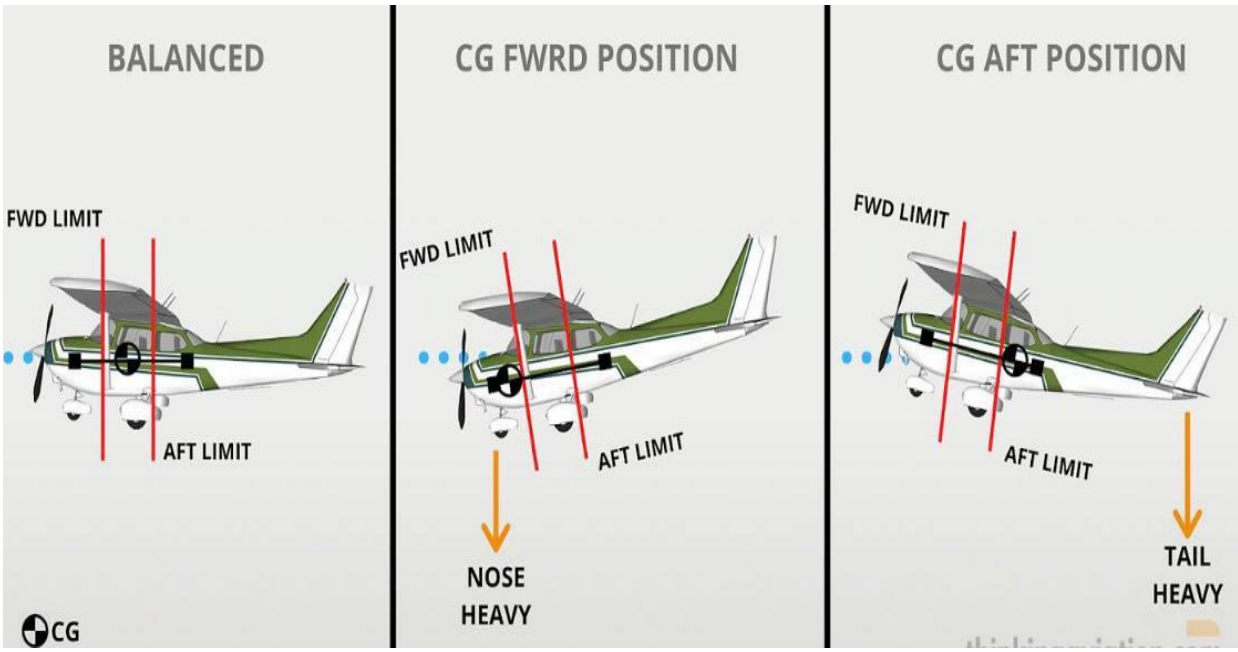
A pilot applies a force of 80 N to the rudder at a distance of 1.5 meters from the hinge line. Calculate the yawing moment.

- Solution:

M = 80 . 1.5 = 120 N.m

5. Center of Gravity (CG) & Stability

The Center of Gravity is the point where the total weight of the aircraft acts. For safe flight, the CG must remain within specific limits.



CG = Σ(mass . distance) / Σ(mass)

Engineering Insight:

- Forward CG → More stability but less maneuverability
- Aft CG → Less stability but higher maneuverability

Example 4: Simplified CG for a Drone

A drone has a frame of 1.2 kg at distance (0) and a battery of 0.8 kg placed 0.2 m forward. Find the new CG.

Sameer.Saad.Raheem@uomus.edu.iq

• Solution:

CG = [(1.2 . 0) + (0.8 . 0.2)] / (1.2 + 0.8)

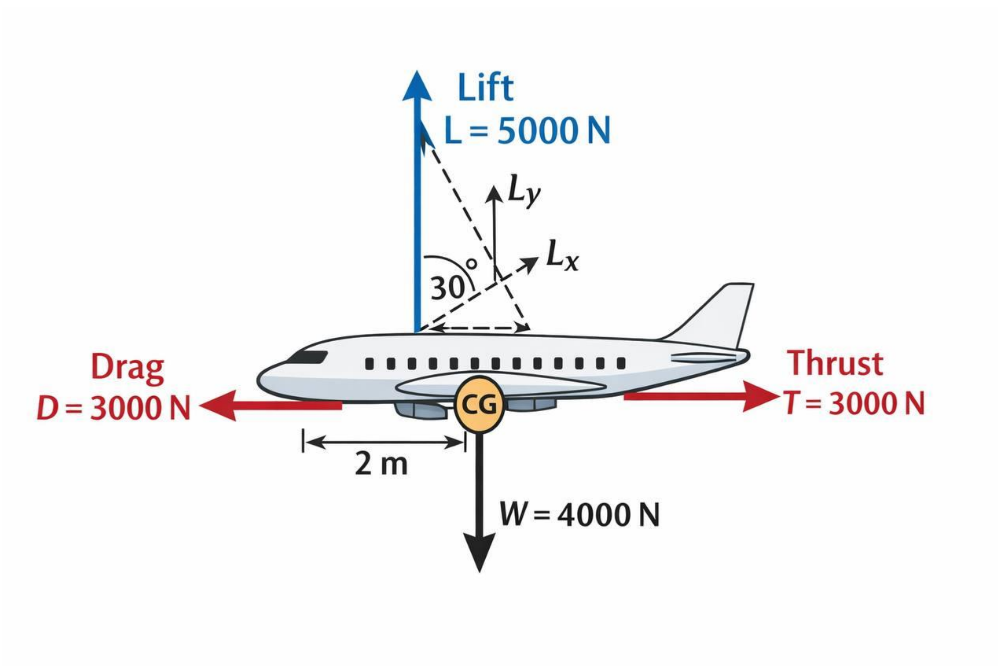
CG = [0 + 0.16] / 2.0 = 0.08 meter forward

Problem Statement

An aircraft wing is subjected to the following forces:

- Lift force L = 5000 N, acting upward at an angle of 30° to the vertical
- Weight W = 4000 N, acting vertically downward at the center of gravity (CG)
- Thrust T = 3000 N, acting horizontally forward
- Drag D = 3000 N, acting horizontally backward

The lift force acts at a distance of 2 *m* from the center of gravity.



Sameer.Saad.Raheem@uomus.edu.iq

Required

1. Resolve the lift force into horizontal and vertical components
2. Check the equilibrium in both x and y directions
3. Calculate the moment about the center of gravity
4. Determine whether the system is in equilibrium

Solution

Step 1: Resolve Lift

$L_y = 5000 \times \cos(30°) = 5000 \times 0.866 = 4330$ N

$L_x = 5000 \times \sin(30°) = 5000 \times 0.5 = 2500$ N

Step 2: Check x-direction

$\Sigma F_x = T - D + L_x$

$\Sigma F_x = 3000 - 3000 + 2500 = 2500$ N

Not in equilibrium

Step 3: Check y-direction

$\Sigma F_y = L_y - W$

$\Sigma F_y = 4330 - 4000 = 330$ N

Not in equilibrium

Sameer.Saad.Raheem@uomus.edu.iq

Step 4: Moment about CG

$M = F \times d$

$M = 4330 \times 2 = 8660\ N\cdot m$

Step 5: Final Result

System is not in equilibrium ($\Sigma F \neq 0$ and $\Sigma M \neq 0$)

6. Summary of Equilibrium Conditions

For any aerospace component to be structurally sound, it must satisfy:

1. $\Sigma F_x = 0$ (No horizontal translation)

2. $\Sigma F_y = 0$ (No vertical translation)

3. $\Sigma M = 0$ (No rotation)

7. Conclusion

Engineering statics is a fundamental tool in analyzing and designing aircraft structures. By understanding forces, moments, and equilibrium conditions, engineers can ensure that all components operate safely under various loading conditions. Mastering these principles is essential for advanced studies in aircraft stress analysis and structural design.

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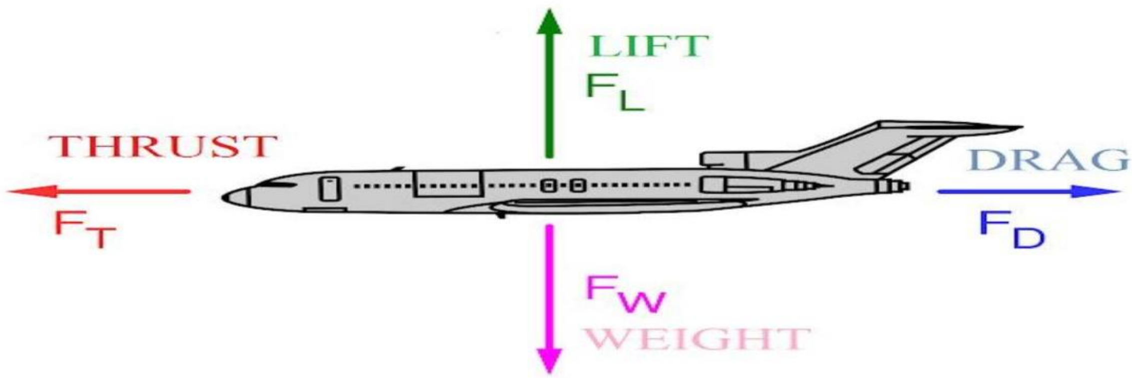
LIFT
F_L
THRUST
F_T
DRAG
F_D
F_W
WEIGHT