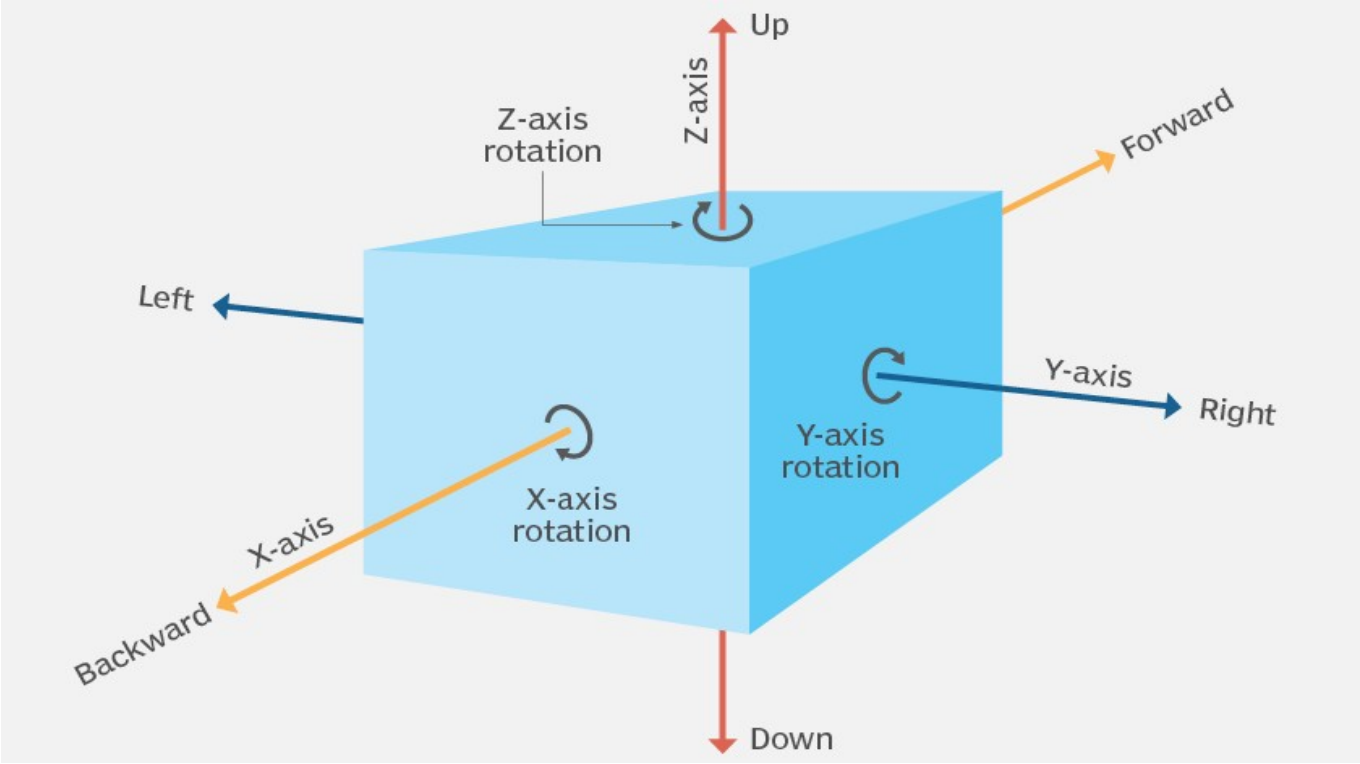
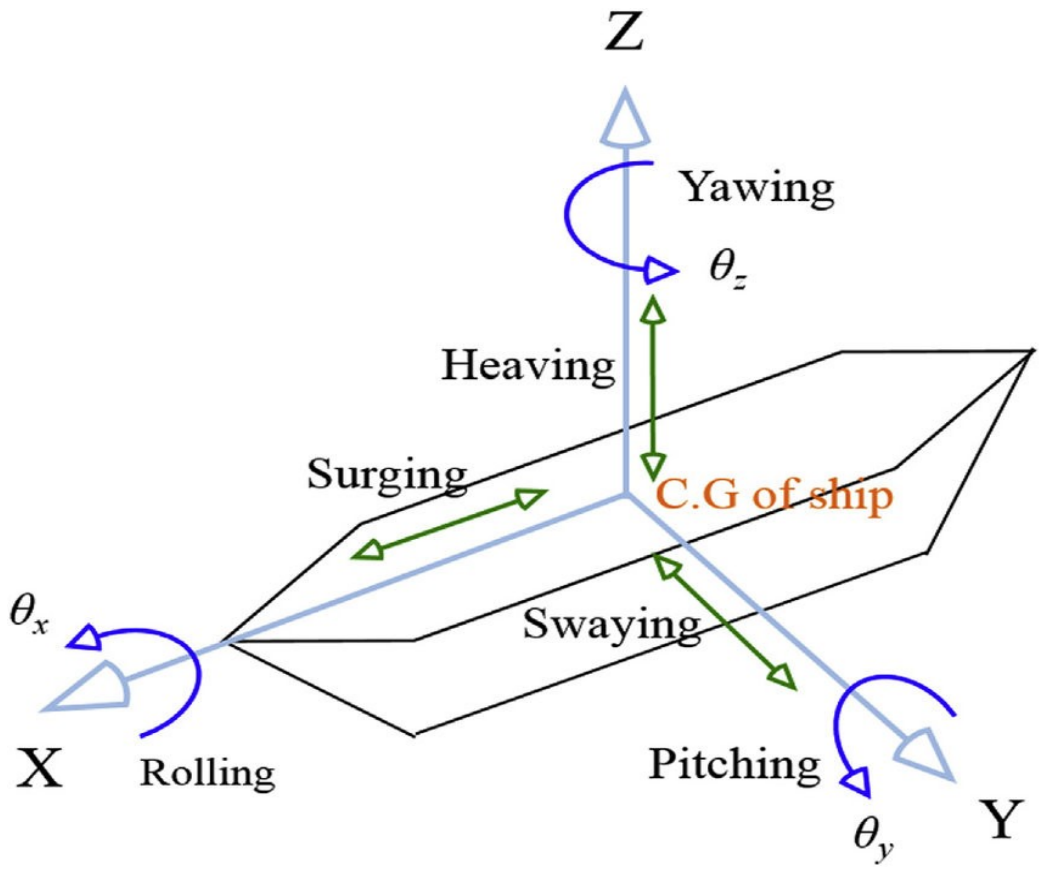
What is degrees of freedom (mechanics)?

In mechanics, degrees of freedom (DOF) is the number of independent variables that define the possible positions or motions of a mechanical system in space. DOF measurements assume that the mechanism is both rigid and unconstrained, whether it operates in two-dimensional or three-dimensional space. The number of degrees of freedom is equal to the total number of independent displacements or aspects of motion.



Degrees Of Freedom of Ship



Centre of Mass

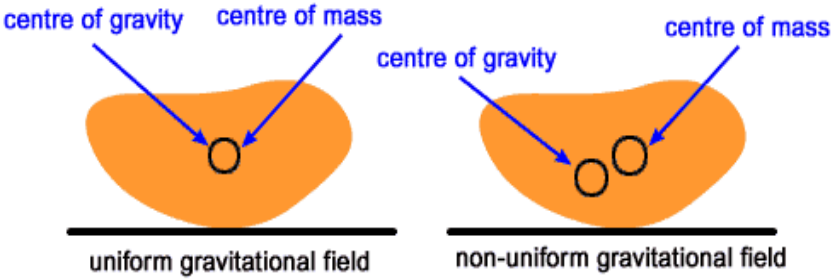
- It is a hypothetical Point where entire mass of an object may be assumed to be concentrated.

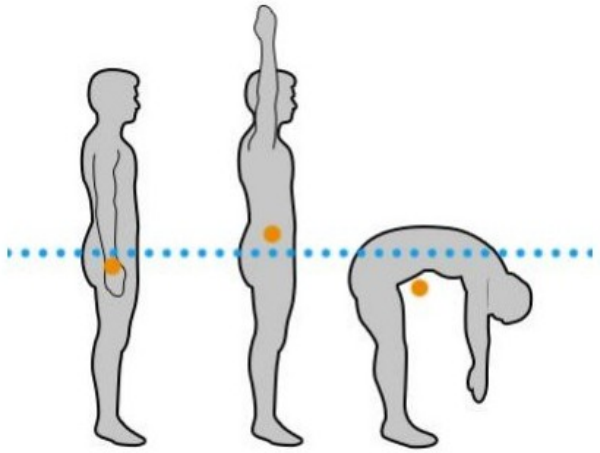
Centre of gravity

- It is a hypothetical Point from which only the gravitational force acts centre of gravity is related to the volume and mass distribution of the body.

Does the centre of gravity and mass lie on the same point?

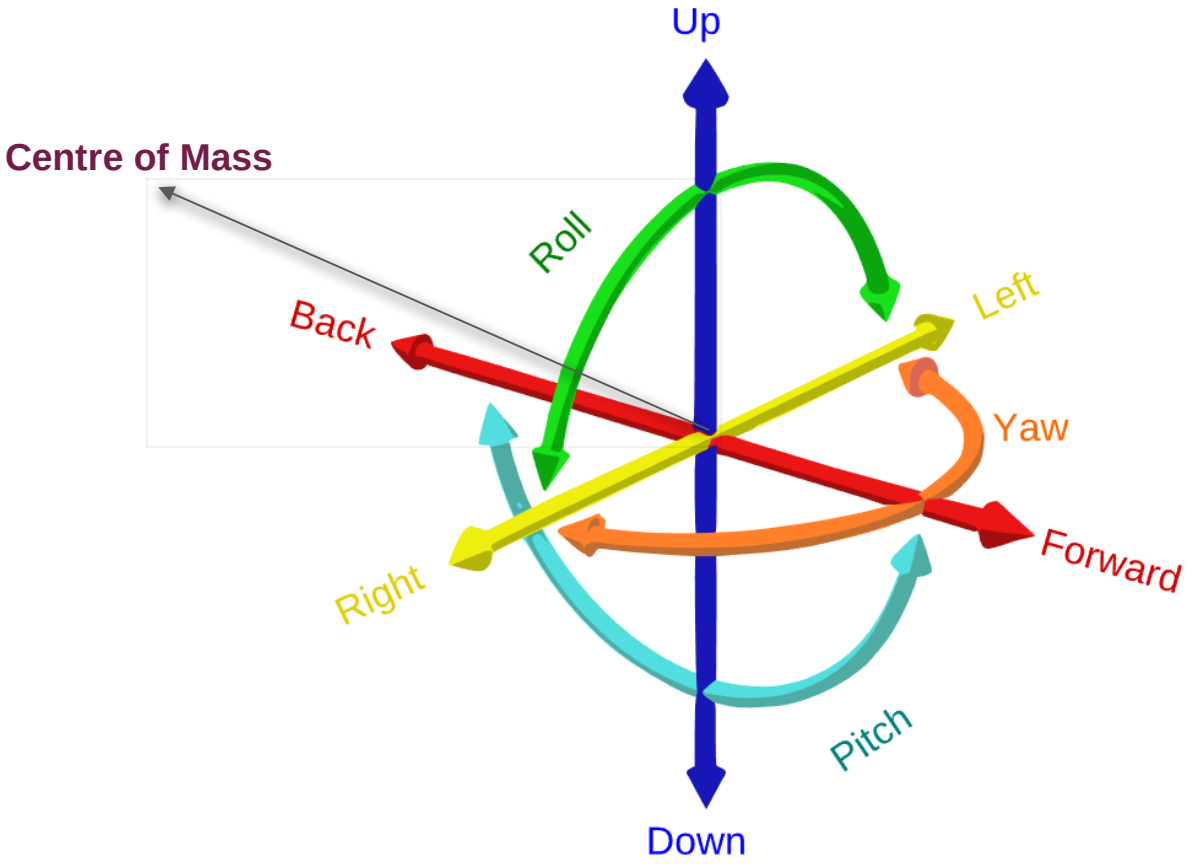
Consider the following very simple analogy. The two balls are identical. They each have the same mass.





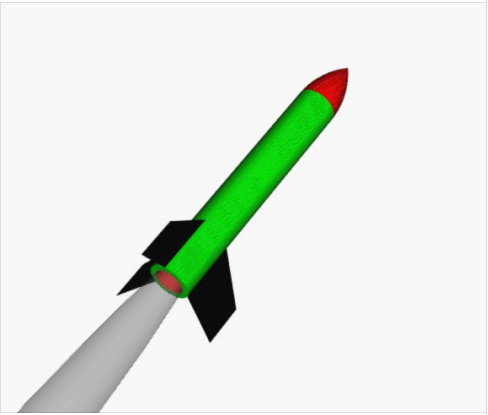
Rocket Dynamics(8 Degrees of freedom for Rocket Motion)

Positive Roll	(+) Θx
Negative Roll	(-) Θx
Positive Pitch	(+) Θy
Negative Pitch	(-) Θy
Positive Yaw	(+) Θz
Negative Yaw	(-) Θz
Forward Thrust	(+) Δx
Drag (Or) Negative Thrust	(-) Δx

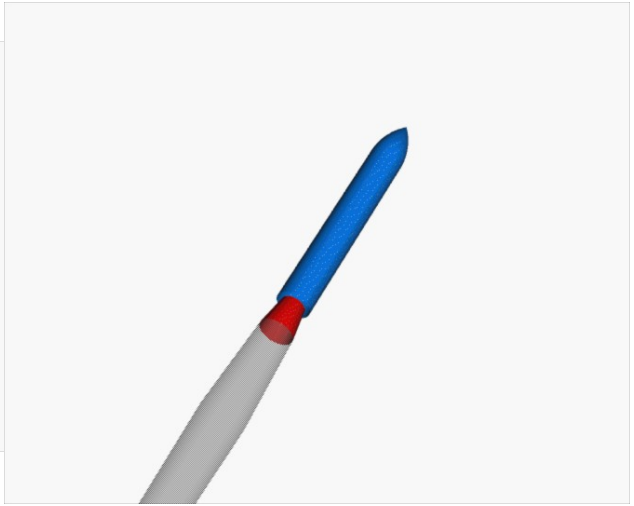

Centre of Mass
Up
Roll
Back
Left
Yaw
Forward
Right
Pitch
Down

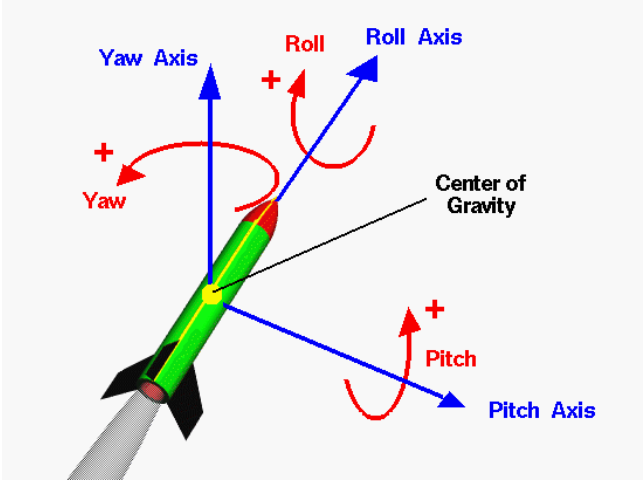
Rocket Roll, Yaw and Pitch

Roll Motion

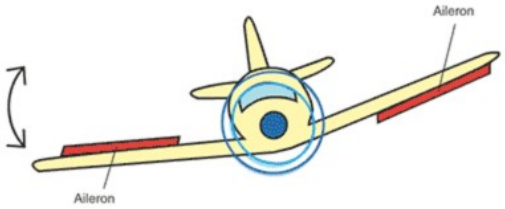


Pitch Motion

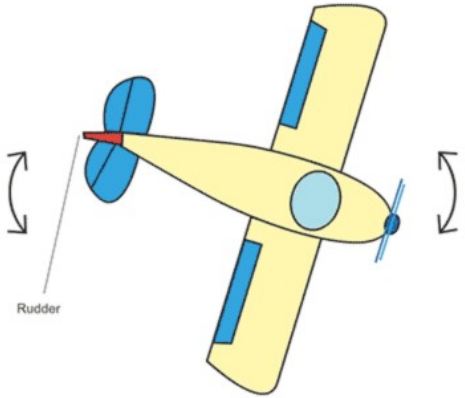




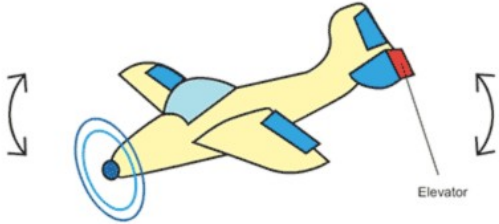
Aircraft Roll,Yaw,Pitch



Use the ailerons to control
Roll



Use the rudder to control
Yaw



Use the elevator to control
Pitch

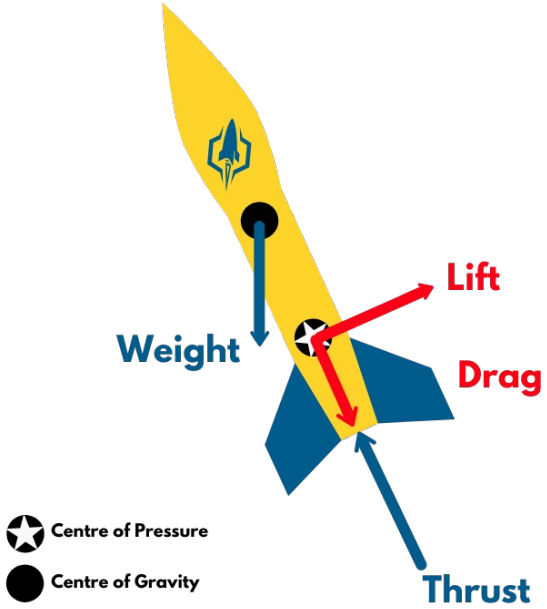
Attitude Control System:

- For the rocket to correct for perturbations and disturbances along its flight path,attitude corrections within these 8-Degrees of Freedom must be continuously made.ACS accomplish this controlled flight.
- In order for the rocket to go in the intended direction,attitude must be monitored and controlled.

Factors Causing perturbations:

- Aerodynamic Drag
- Solar Radiation
- Gravitational Torque (Or) Gradients
- Internal Movement and Misalignment

Perturbations in Rockets Trajectory



Cp = Sum Total of Aerodynamic forces on an object is acting. And it is related to the area of a body subjected to uniform pressure.

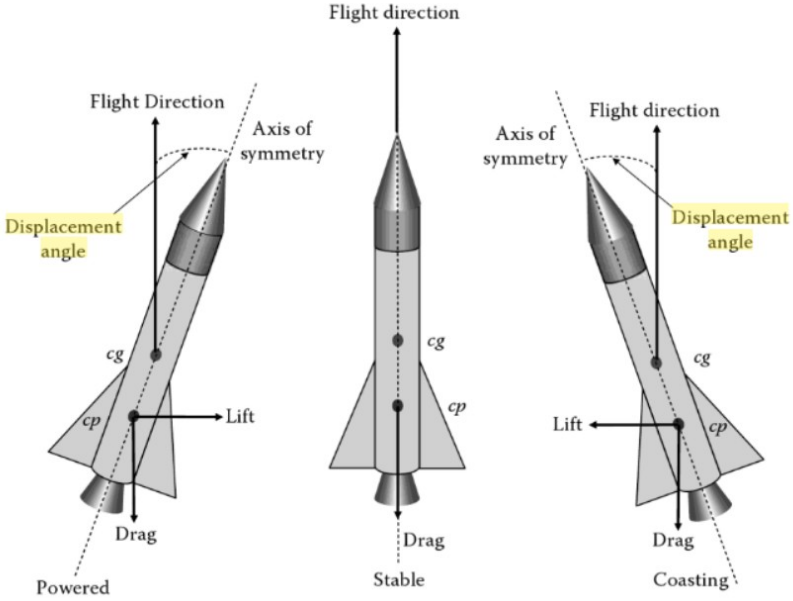
Forces acting on a rocket

1. Weight,
2. Thrust,
3. Lift and
4. Drag

The crucial aspect of flight dynamics is that these four forces incident on the rocket are ever changing in direction and magnitude throughout the flight as they are vectors.

Lift can be generated by rocket body and fins whenever the rocket is inclined to the flight path.

Introduction to Torque and Influence of the position of Cg and Cp in Rockets



Coasting Rocket:

- Rocket nose is perturbed to the left which result lift force is acting towards the left or downward side of the rocket.
- Now both the lift and the drag produce clockwise torques about Cg which causes the tail of the rocket to swing towards left thereby nose will move to right.

Torque:

Force which do not pass through Cg which is by definition of rotation.It is the force multiplied by the distance at which it acts from the axis of rotation.

Stable:

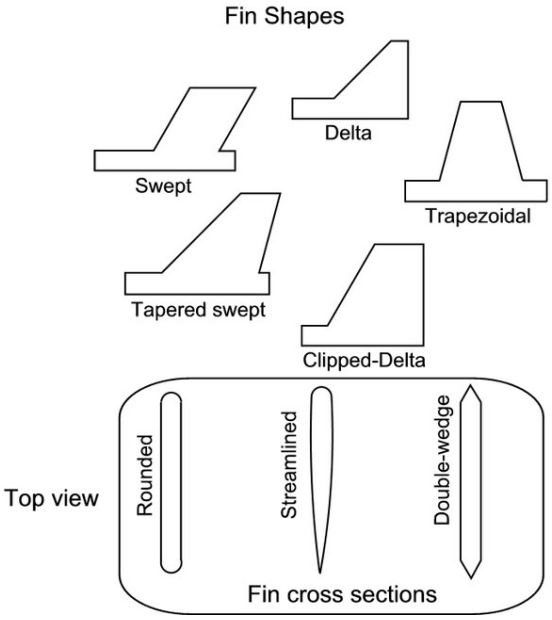
Stable scenario is where rocket is undisturbed and the axis of thrust is aligned with flight direction.

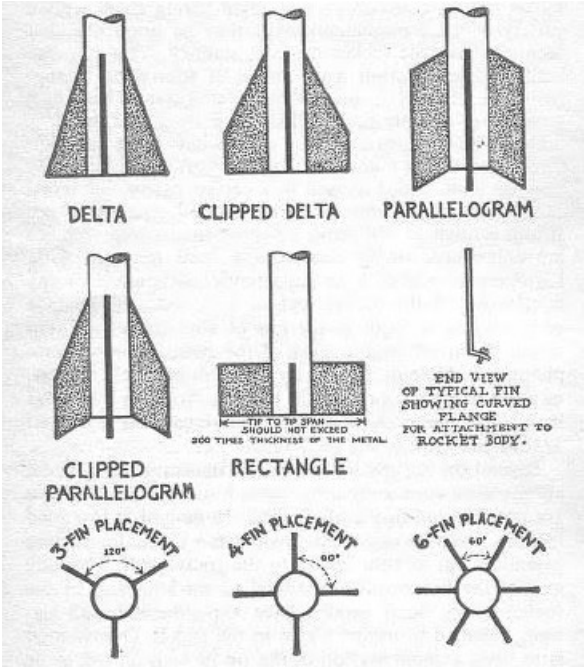
Powered Rocket:

- Rocket nose perturbed to the right which turns it to clockwise about Cg
- It also results in a Lift force directed towards the right or downward side of the rocket.
- Both the Lift and Drag produce counter clockwise torque twists about the Cg which causes the tail of the rocket to swing towards right under the action of both forces and thereby the nose will move to left.This will bring the rocket into stable position.

Passive Stability and Control of Rockets

Fins are increasing surface area at the bottom.It could be made out of lightweight materials and be streamlined in shape.The larger surface area of the fins easily keeps the Cp behind the Cg.





Active Stability and Control of Rockets