CUBE NOTES

Class 11/12 | AP Physics | IIT JEE | NEET

Torque - Rotational Force

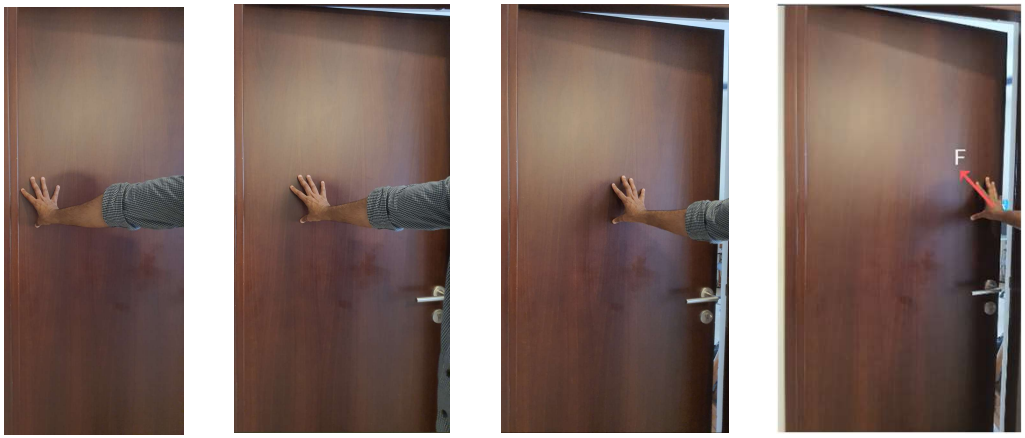
What is Torque?

Torque, means "to twist".

It is the turning effect of a force applied at a distance from the axis of rotation

Real-Life Example: Trying to open a door from the inner edge versus the outer edge illustrates how torque works.

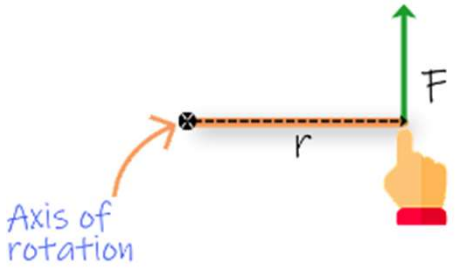
From experience you can say, the twisting force or torque on the door increases as the distance from the hinge (axis of rotation) to the point of force application increases.



Increasing turning effect (torque) for the same force as you move away from the axis of rotation

Calculating Torque

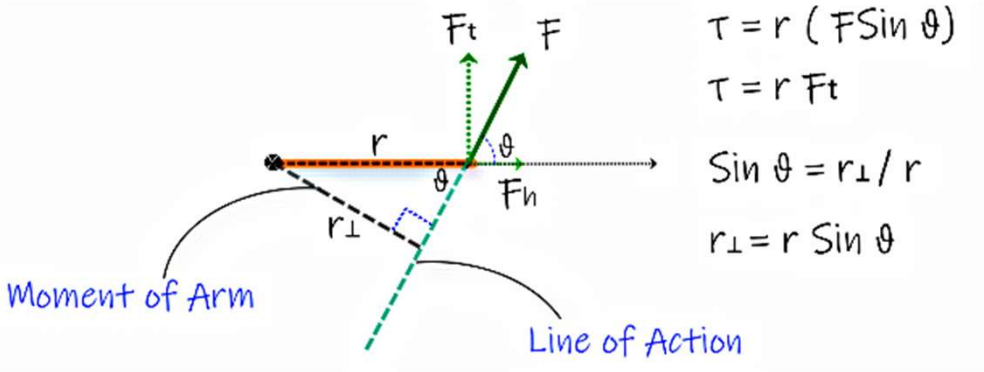
Basic Formula: Torque (τ) is the product of the applied force (F) and its perpendicular distance (r) from the axis of rotation.



$$\tau = r\,F$$

If F and r make an angle θ with each other –

$$\tau = r \times F = r\,F \sin(\theta)$$



Where:

- r = Distance from the pivot (moment arm)
- F = Force applied
- θ = Angle between force and moment arm

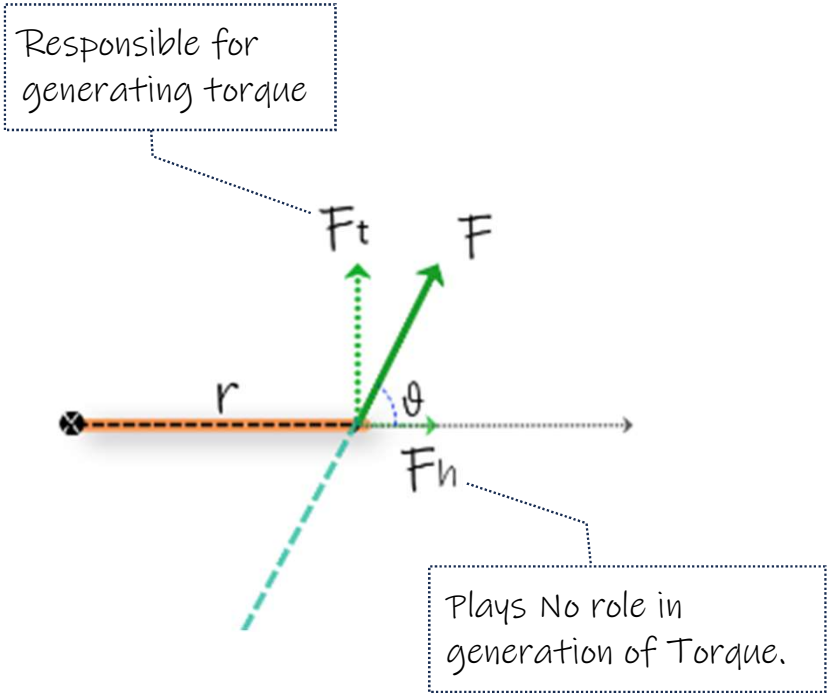
Units: Newton-meter (N·m)

Components of Force in Torque

Torque is the rotational equivalent of force, a measure of how much a force causes an object to rotate around a pivot.

1. **Tangential Force (F_t)**: The component of the force that acts perpendicular to the radius vector, contributing to the rotation.

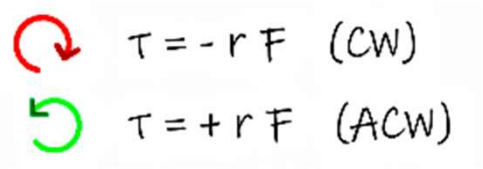
2. **Radial Force (F_r)**: The component of the force along the radius vector, which does not contribute to rotation.



Direction of torque

Sign Convention

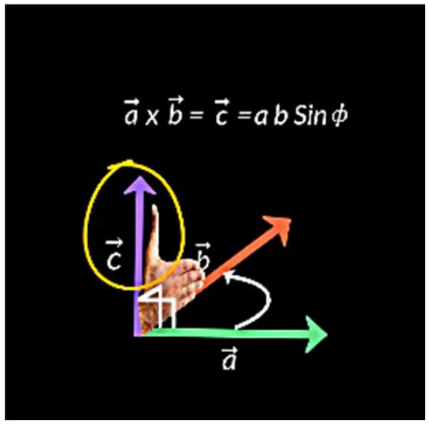
Clockwise rotation: Negative Torque
Counterclockwise rotation: Positive Torque



Torque as a Vector

$$\tau = r \times F$$

Direction: Perpendicular to the plane of rotation. Use Right hand Rule to establish the direction



Sweep the palm of your hand from the first vector appearing in the cross product ("a" in this case) towards the 2nd vector. Then the direction of the thumb gives the direction of the resultant vector

Important Equations

Equation	Explanation of Variables	Caution / Notes
$\tau = r \times F$ (Vector Form)	τ: Torque vector, r: Position vector, F: Force vector	Apply the right-hand rule to determine the direction of the torque vector τ. It points along the axis of rotation.
$\tau = r F \sin(\theta)$	τ: Torque, r: Distance from pivot, F: Magnitude of force, θ: Angle between F and r	Ensure that the angle θ is measured between the force vector F and the position vector r.
$\tau = (r \sin \theta)(F) = r_{\perp}F$	$r_{\perp}$ is the perpendicular distance between the rotation axis at O and an extended line running through the vector F.	This extended line is called the line of action of F, and $r_{\perp}$ is called the moment arm of F.
$\tau = r F$	τ: Torque, r: Perpendicular distance from the axis of rotation, F: Force	This form is valid only when the force is entirely perpendicular to the radius vector r.