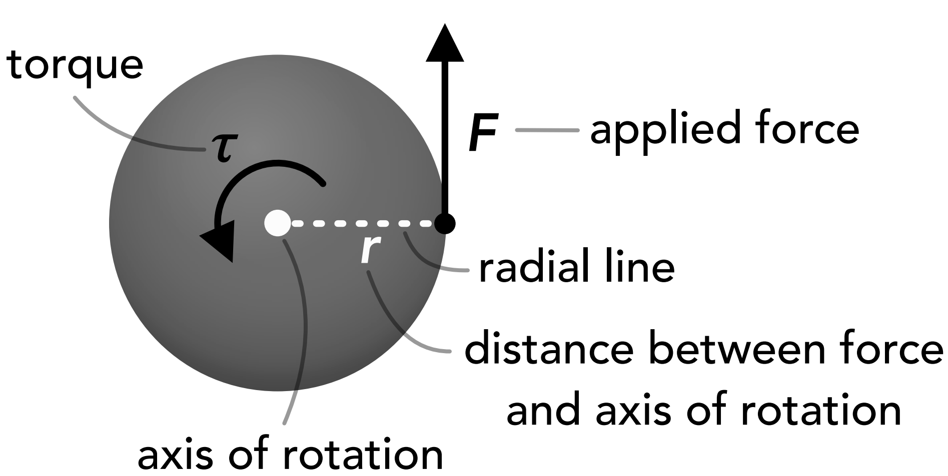
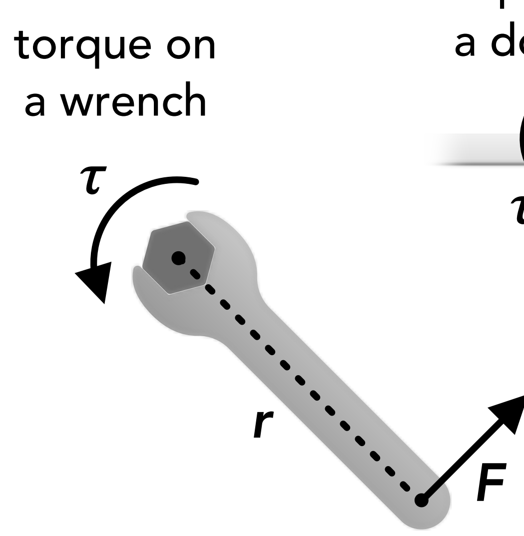
TORQUE

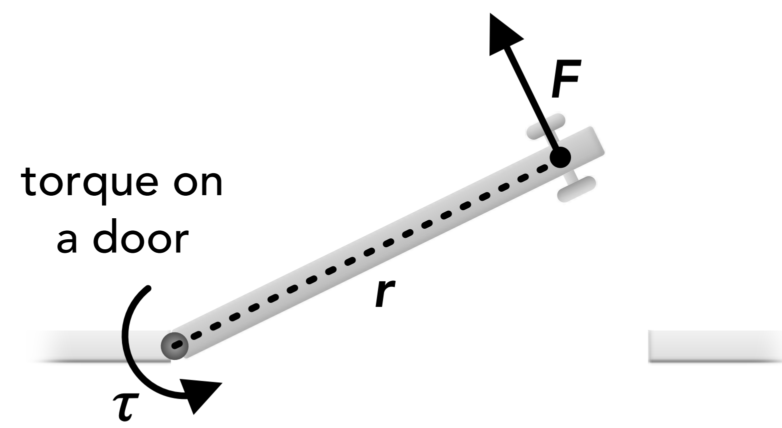
Torque

- In simple terms, **torque** is like a **rotational force**.
- When a force is applied to an object and that force does not point directly at or away from the object's axis of rotation, that force **generates a torque**.
- If an object is forced to rotate around one point or axis, like a wheel rotating about an axle or a door rotating about a hinge, **that is the axis of rotation**. If an object is free to rotate about any axis, its axis of rotation will pass through its **center of mass**.

Variables		SI Unit
τ	torque	N·m
F	force	N
r	distance from rotation axis	m







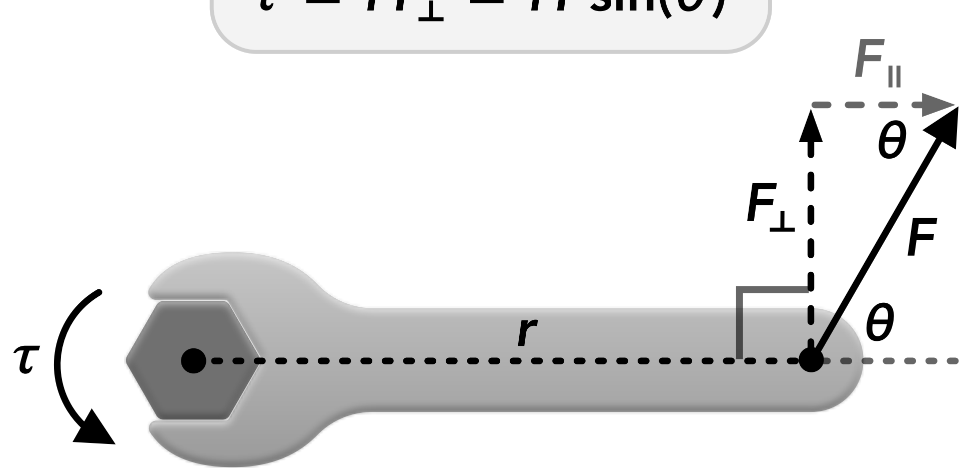
- When you push or pull on a door or a wrench, you're applying a linear force at some distance from the object's axis of rotation and generating a torque on that object which causes it to rotate.

- Torque is represented with the Greek letter τ (tau).
- The SI unit of torque is Newton-meters (N·m) which is given by the equation below.
- Only the component of the force that is **perpendicular** to the radial line between the center of rotation and the point where the force is applied contributes to the torque.
- If the force is not already perpendicular to the radial line, there are two ways to calculate the torque:

Multiply the distance between the axis of rotation and the point where the force is applied (r) times the component of the force vector that is perpendicular to the radial line ($F_\perp$)

Torque

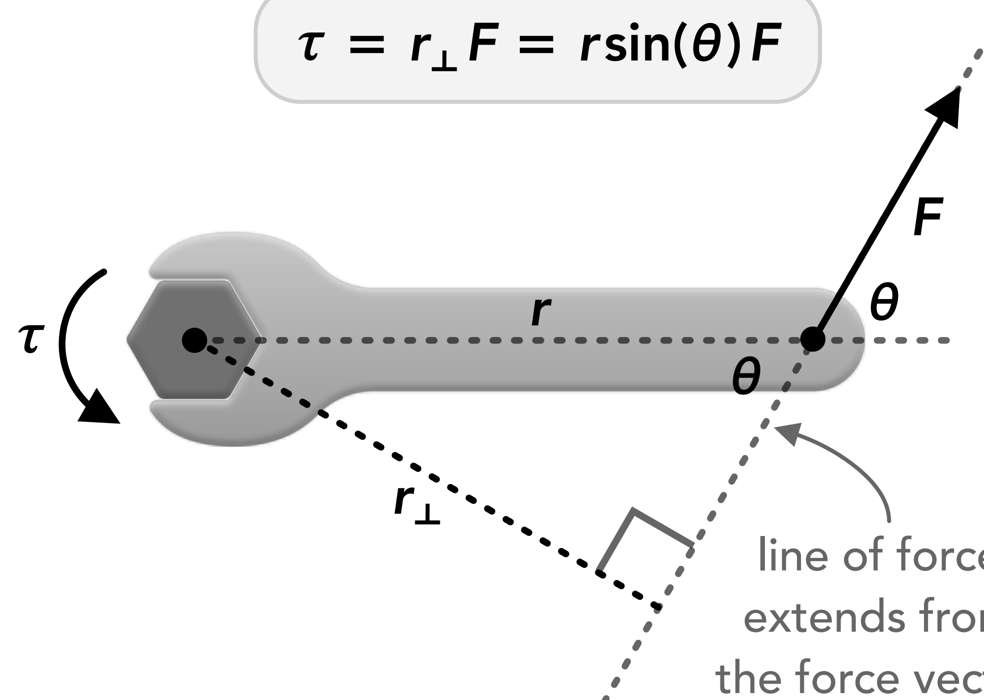
$$\tau = rF_\perp = rF\sin(\theta)$$



Multiply the perpendiuclar distance between the axis of rotation and the line of force ($r_\perp$) times the force (F)

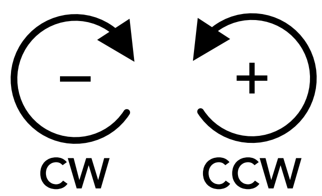
Torque

$$\tau = r_\perp F = r\sin(\theta)F$$

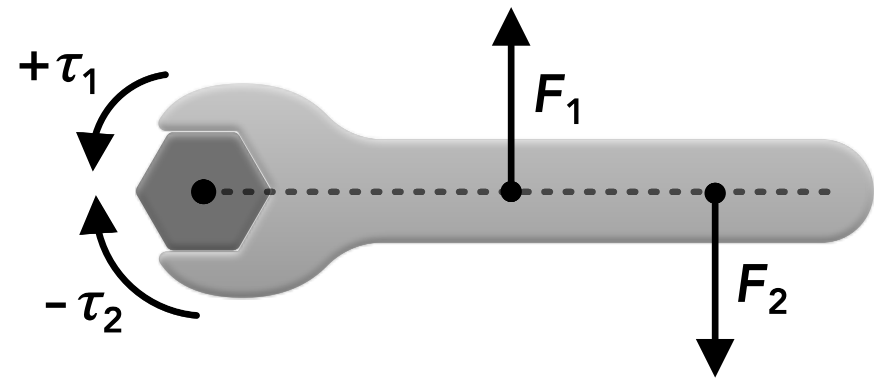


- When looking at the plane of rotation, a torque can either be clockwise (CW) or counterclockwise (CCW).
- **Counterclockwise is the positive direction** using convention, and clockwise is the negative direction, just like in rotational or circular kinematics. This is important when adding several torques to find the net torque.
- The direction of the torque is the direction that the force would cause the object to rotate (CW or CCW).

counterclockwise torque is positive
clockwise torque is negative



F_1 would rotate the wrench counterclockwise so it generates a positive torque



F_2 would rotate the wrench clockwise so it generates a negative torque

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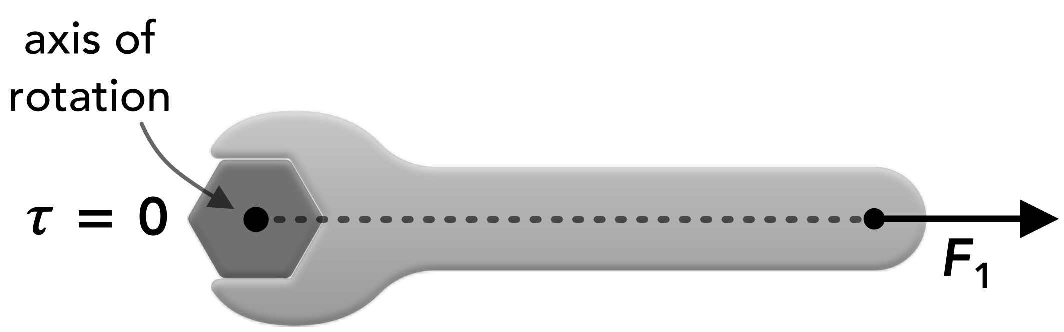
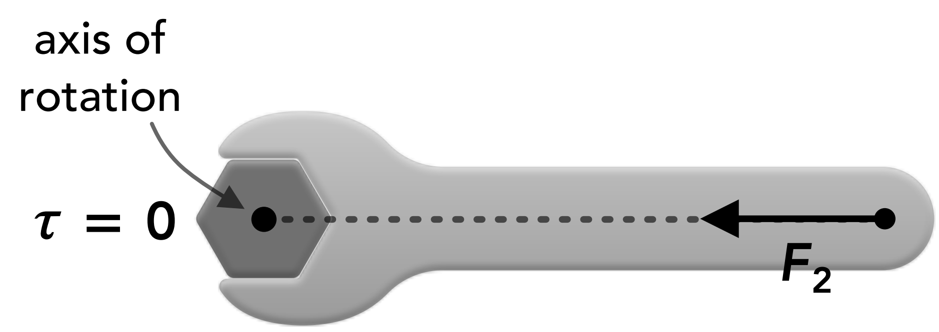
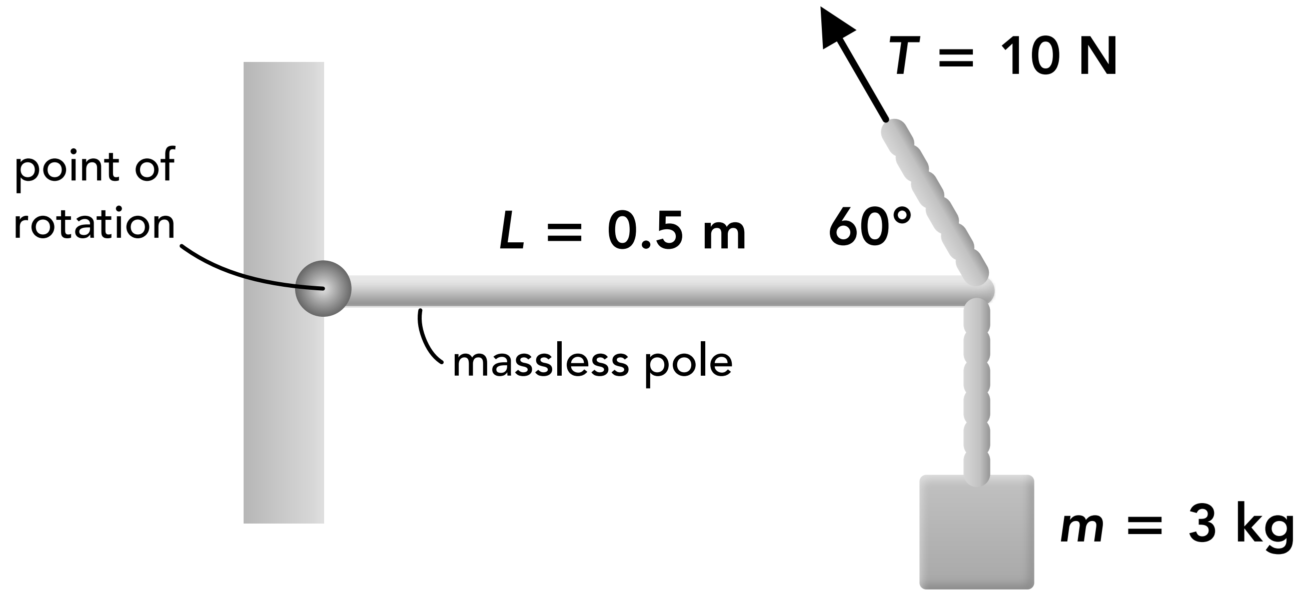
- A force whose line of force passes through the axis of rotation (the force points directly at or away from the axis of rotation) **does not generate a torque** because there is no force component perpendicular to the radial line.

F_1 and F_2 do not generate a torque because they act parallel to the radial line (directly at or away from the axis of rotation)

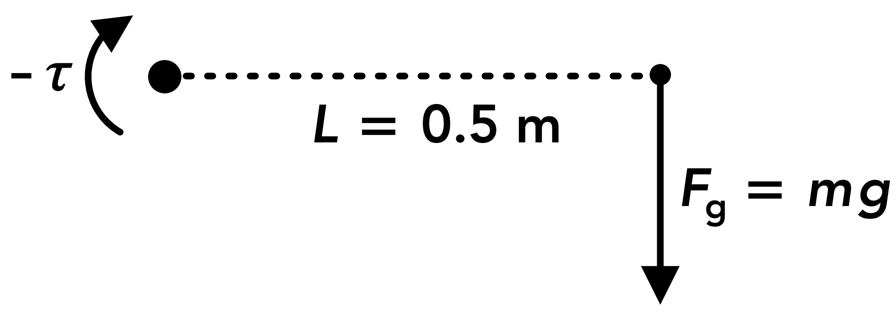




Example: A massless pole is pinned to a wall and is free to rotate about its left end. At the right end of the pole a mass is hanging straight down and a rope pulls the pole up with a tension force at an angle. What are the torques generated by the hanging mass and the tension force about the point of rotation on the left?



Torque from hanging mass:



$\tau = rF_\perp$

$\tau = (L)(mg)$

$\tau = (0.5\text{ m})(3\text{ kg})(9.8\text{ m/s}^2)$

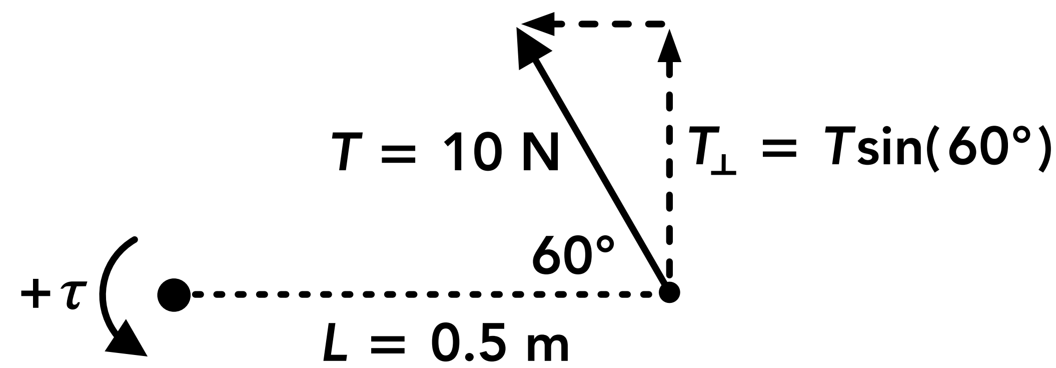
$\tau =$ **14.7 Nm** (magnitude of torque)

↓

$\tau =$ **-14.7 Nm**

torque is clockwise so it's negative

Torque from upper rope:



$\tau = rF_\perp$

$\tau = (L)(T\sin(60°))$

$\tau = (0.5\text{ m})(10\text{ N})\sin(60°)$

$\tau =$ **4.3 Nm** (magnitude of torque)

↓

$\tau =$ **4.3 Nm**

torque is counterclockwise so it's positive