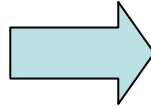


Cross Product, Torque, and Static Equilibrium

Point Masses



Rigid Bodies

Generalization of Newton's Laws:

- External forces accelerate the **center of mass**
- External **torques** cause angular acceleration

Torque

Quantitative measure of the tendency of a force to cause or change the rotational motion of a body!

Sign convention:

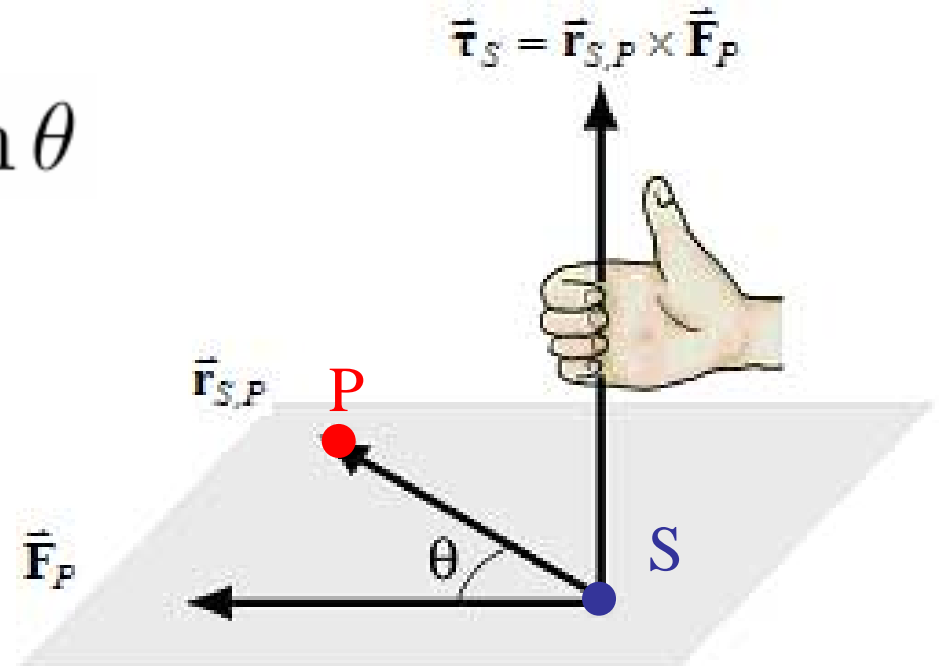
Counterclockwise always positive!

- (1) Magnitude of the torque about S

$$|\vec{\tau}_s| = |\vec{r}_{S,P}| |\vec{F}_P| \sin \theta$$

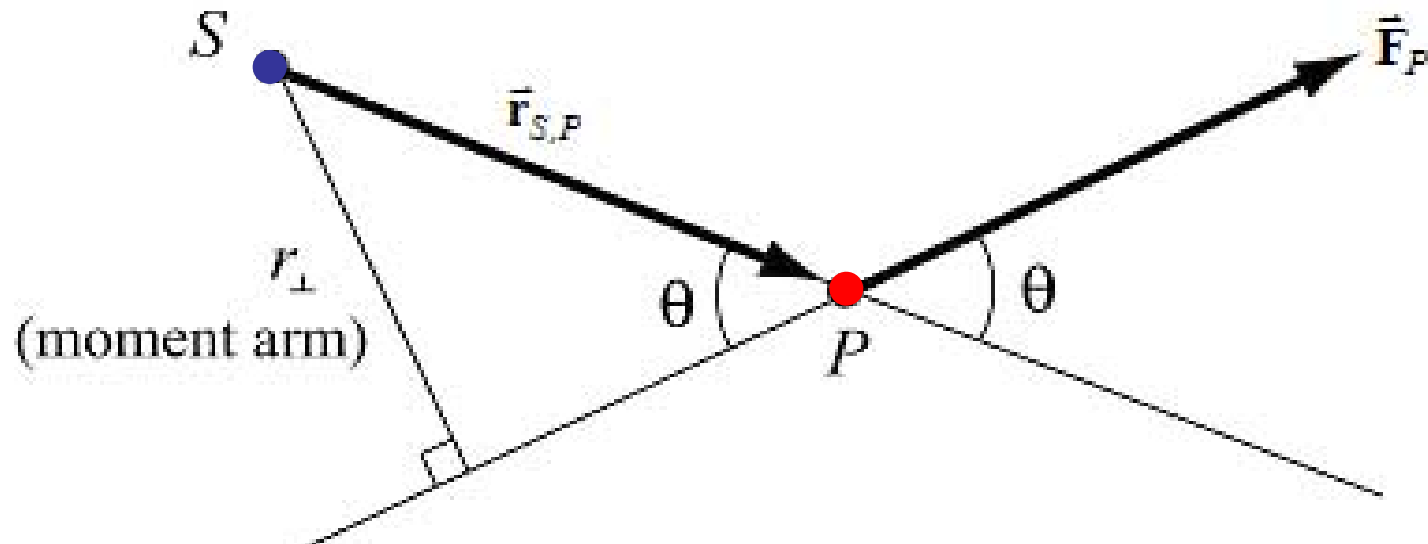
- (2) Direction

$$\vec{\tau}_s = \vec{r}_{S,P} \times \vec{F}_P$$



Moment Arm of the Force

- Moment Arm:

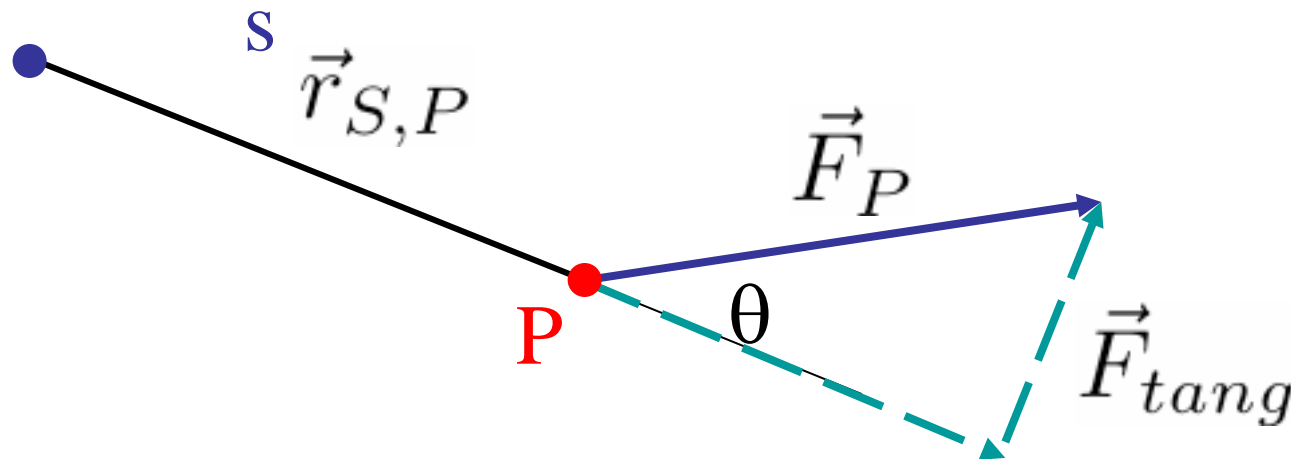


- Torque:

$$|\vec{\tau}_s| = +r_\perp |\vec{F}_P| = |\vec{r}_{S,P}| \sin \theta |\vec{F}_P|$$

Torque from Tangential Force

Break the force into components parallel and perpendicular to the displacement of the force from the axis of the torque:



$$|\vec{\tau}_s| = |\vec{r}_{S,P}| |\vec{F}_{tang}| = |\vec{r}_{S,P}| |\vec{F}_P| \sin \theta$$

Static Equilibrium

(1) The sum of the forces acting on the rigid body is zero:

$$\Sigma \vec{F} = 0$$

(2) The vector sum of the torques about any point S in a rigid body is zero:

$$\Sigma \vec{\tau}_{ip} = 0$$

PRS Question

You are using a wrench to loosen a rusty nut. Which of the arrangements shown is most effective in loosening the nut?

