April 12, Week 12

Today: Chapter 10, Torque

Homework Assignment #9 - Due Today.

Mastering Physics: 7 problems from chapter 9

Written Question: 10.80

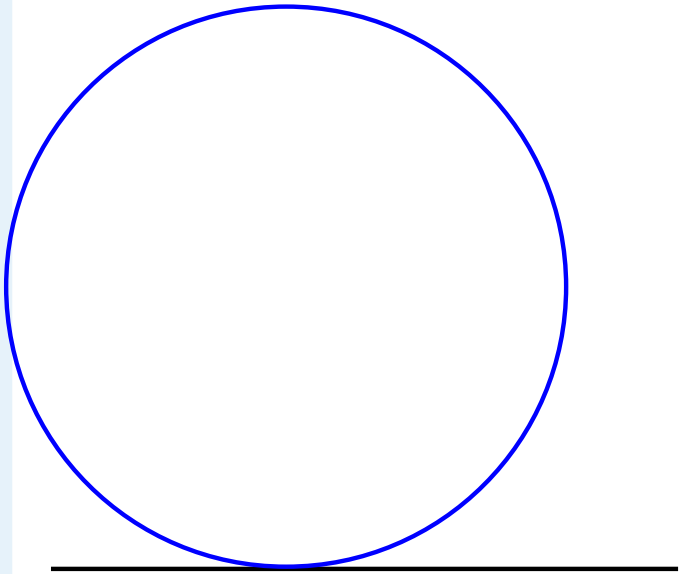
Homework Assignment #10 - Due April 19.

Mastering Physics: 7 problems from chapter 9

Written Question: 10.86

Rolling

When an object rolls, it rotates and its center moves.



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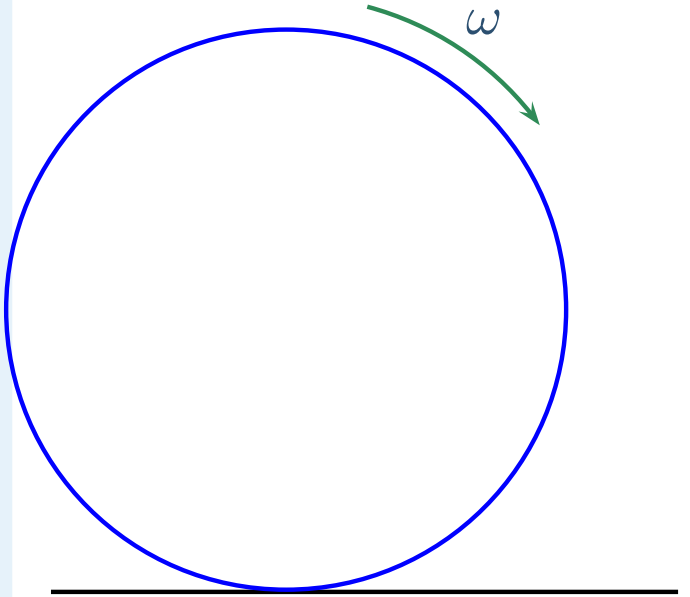

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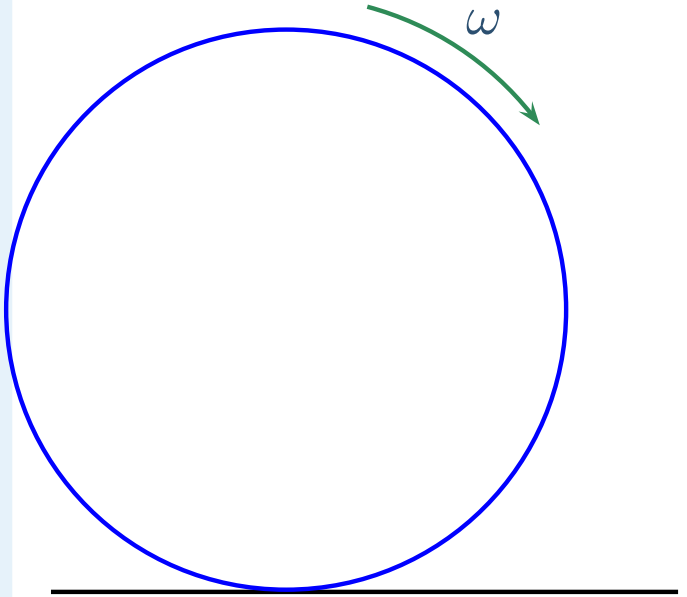

Rotational: $K_r = \frac{1}{2} I \omega^2$

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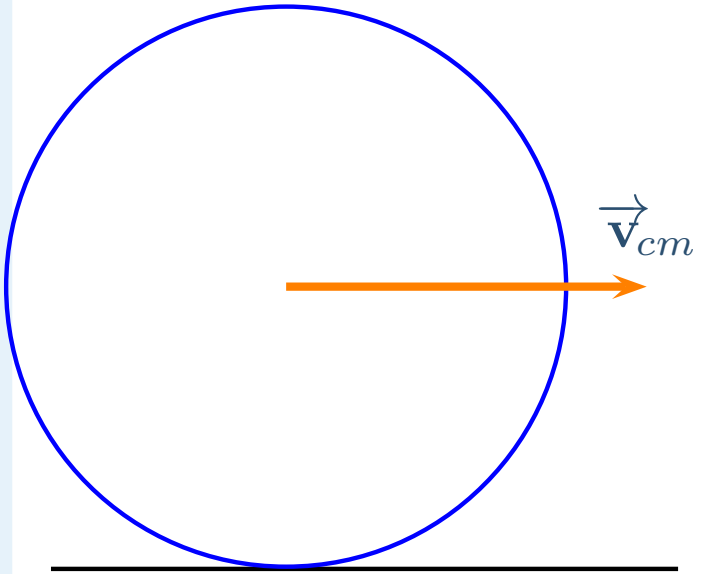

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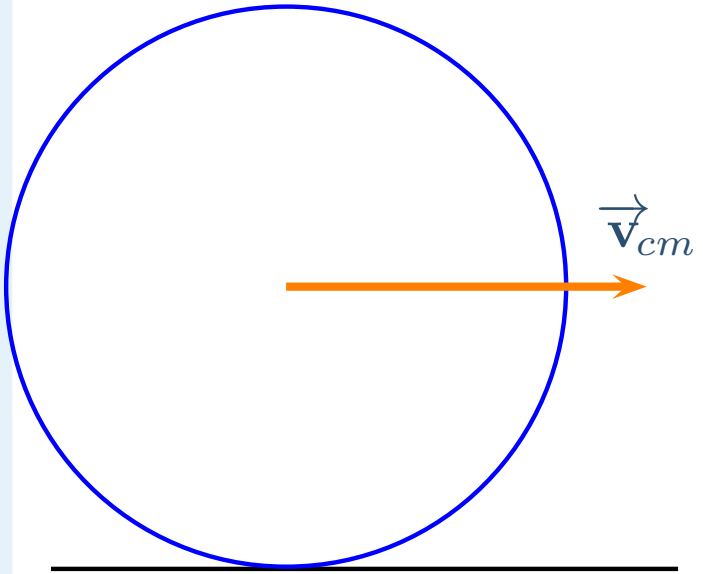

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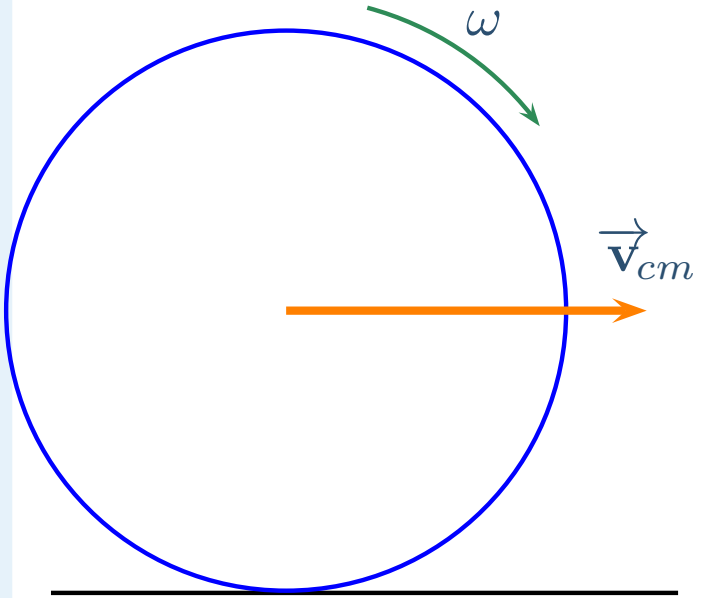

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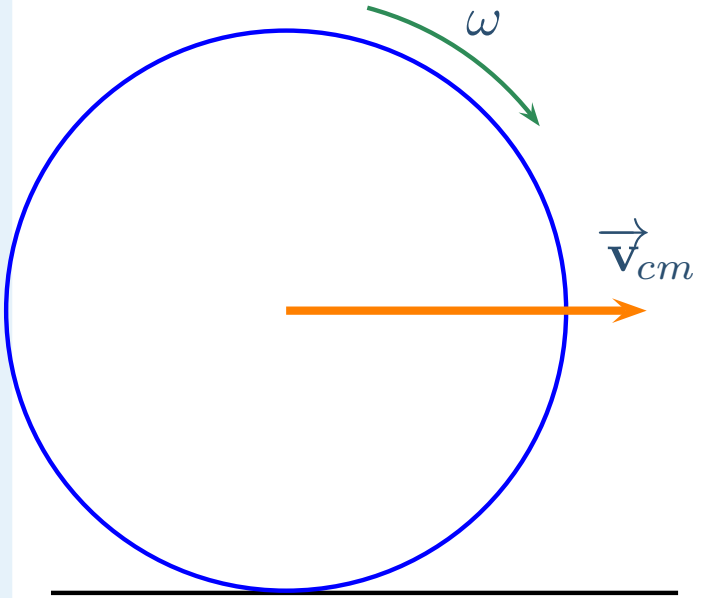

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Total: $K = K_t + K_r = \frac{1}{2}mv_{cm}^2 + \frac{1}{2}I\omega^2$

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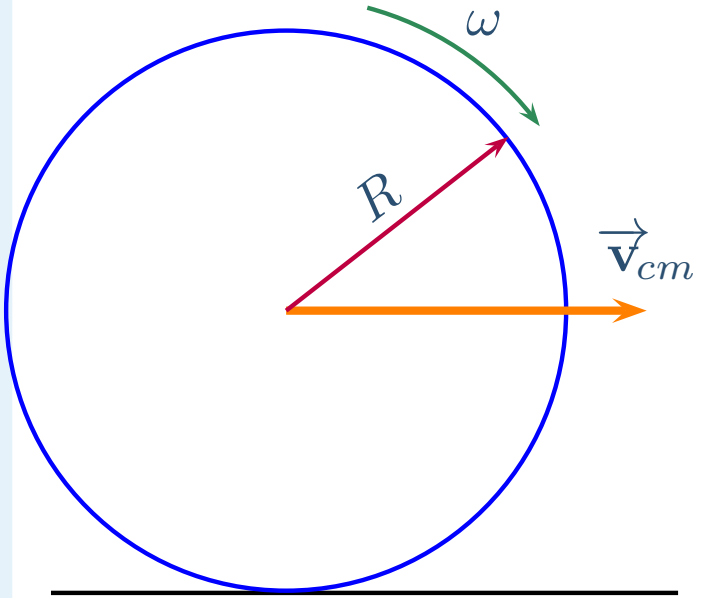

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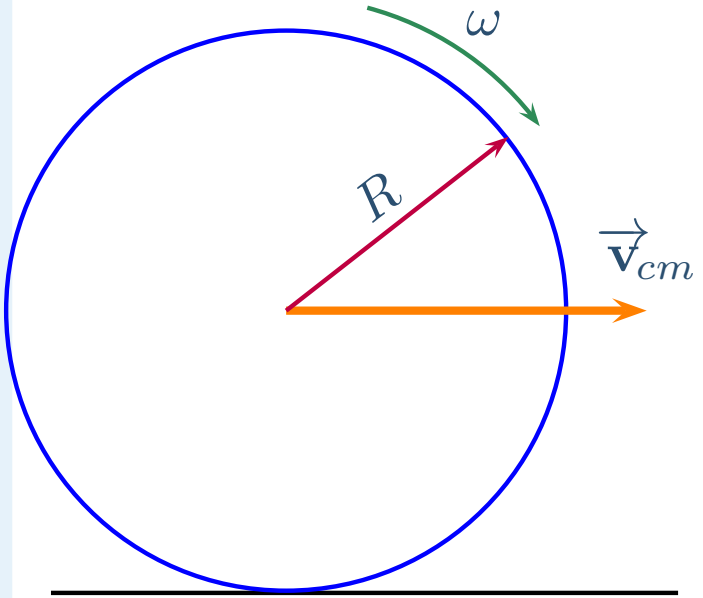

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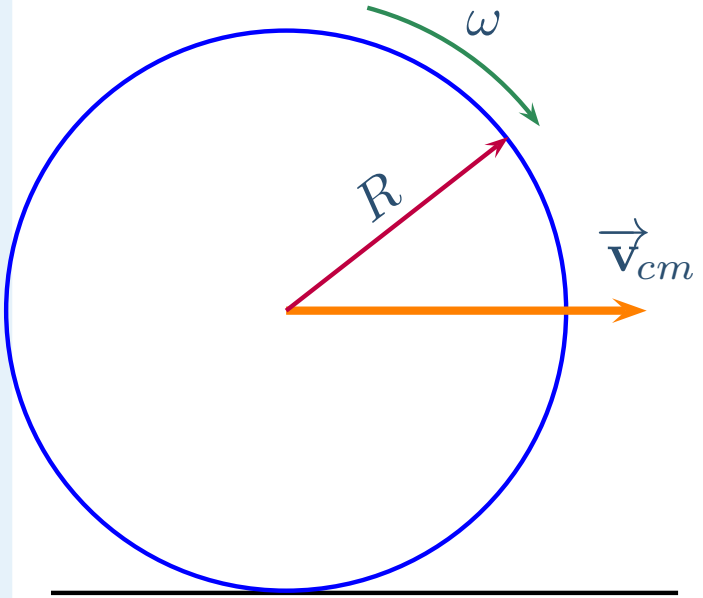

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$$K = \frac{1}{2}mv_{cm}^2\left(1 + \frac{I}{mR^2}\right)$$

Rolling Exercise

Two cylinders are started from rest at the top of a slide. They have the same mass and radius, but one is solid the other is hollow. If they are started simultaneously and roll without slipping down the incline, which of them reaches the bottom first. **Hint:** The moment if inertia of a solid cylinder is $\frac{1}{2}MR^2$ while that of a hollow cylinder is MR^2.

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(b) The solid cylinder.

Rolling Hollow Cylinder: $K = \frac{1}{2}Mv^2\left(1 + \frac{MR^2}{MR^2}\right) = Mv^2$

Rolling Solid Cylinder: $K = \frac{1}{2}Mv^2\left(1 + \frac{\frac{1}{2}MR^2}{MR^2}\right) = \frac{1}{2}Mv^2(\frac{3}{2}) = \frac{3}{4}Mv^2$

Torque

Torque, τ - Measures the effectiveness of a force at causing rotation.

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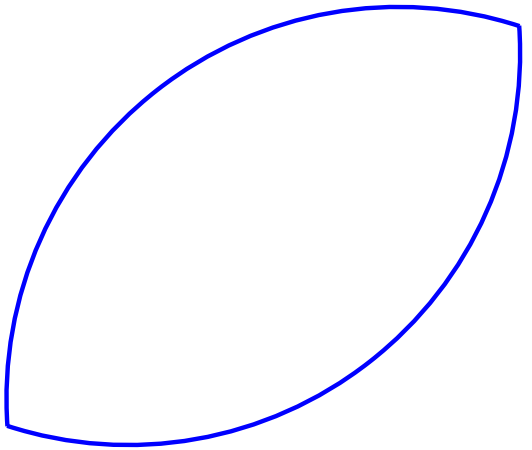

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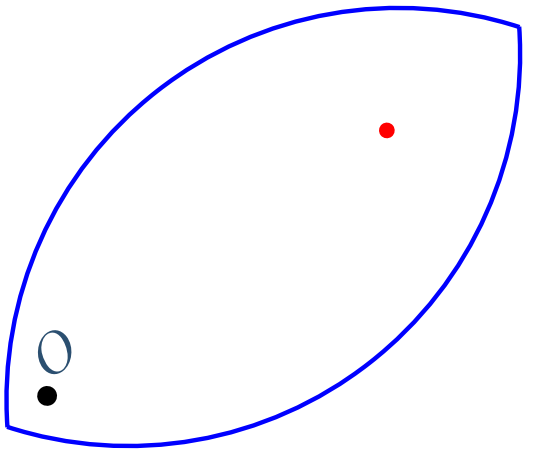

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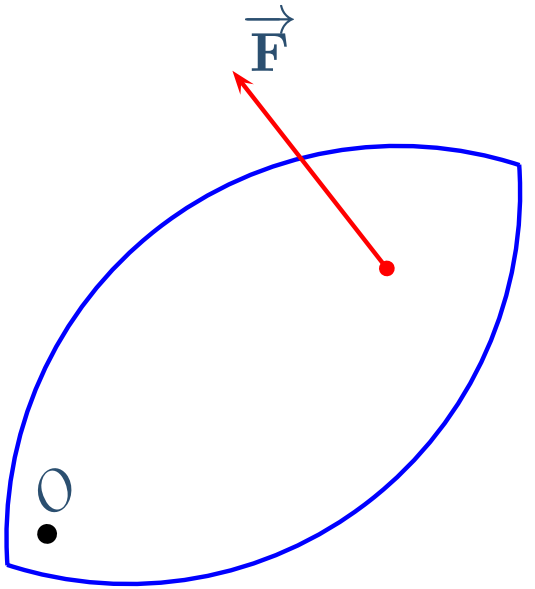

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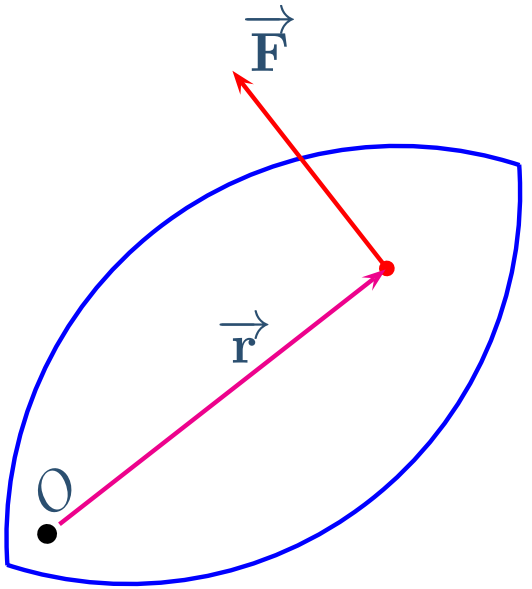

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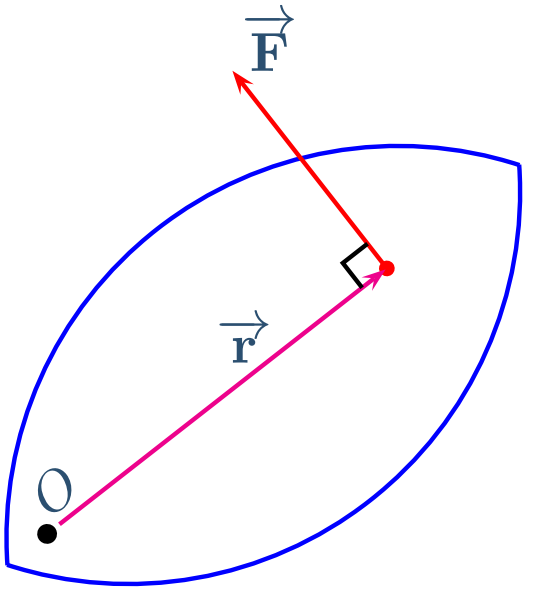

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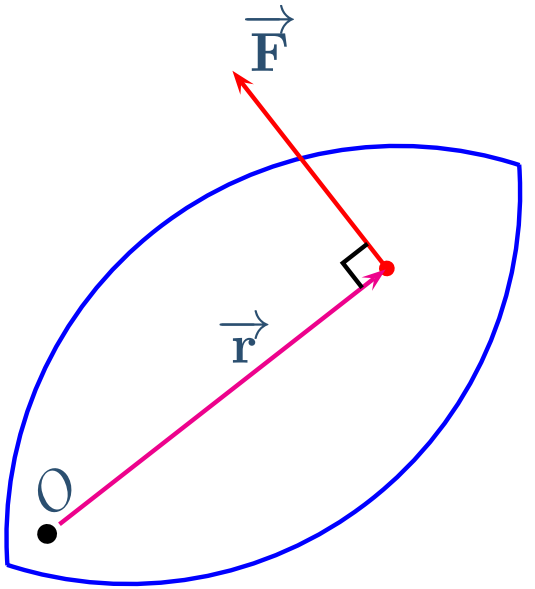

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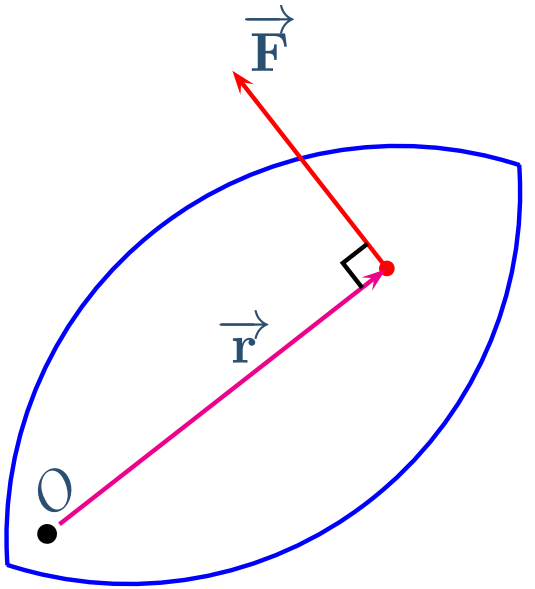

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Torque Exercise

For the three situations shown, which is the correct ranking of torque from smallest to largest?

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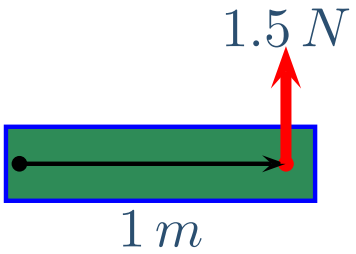

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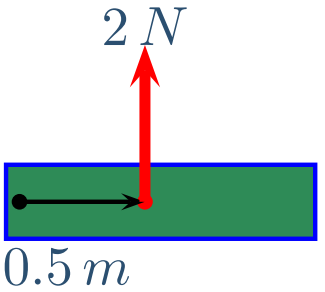

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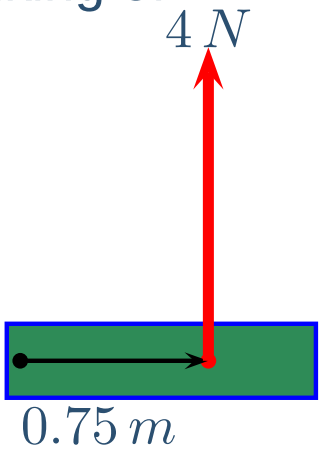

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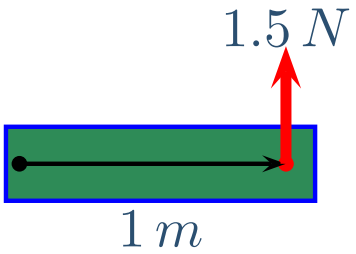

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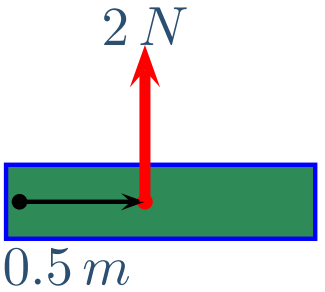

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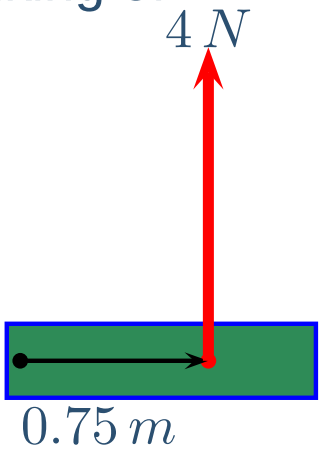

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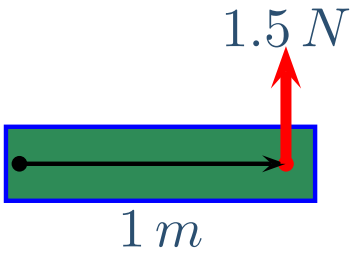

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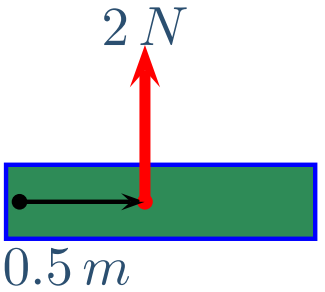

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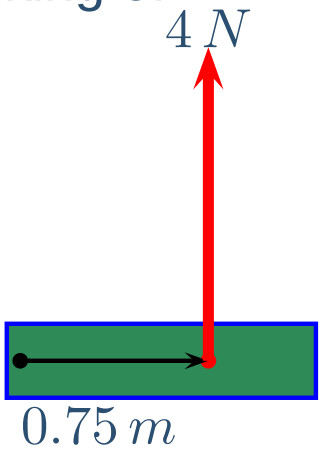

(a) 1,2,3

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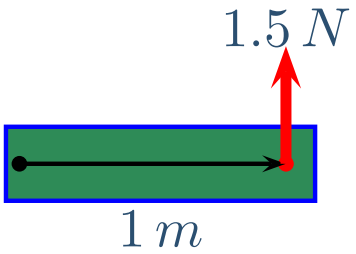

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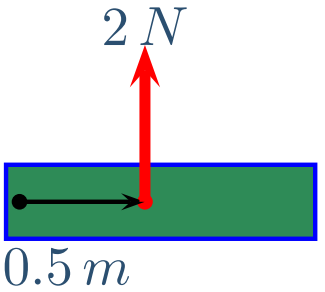

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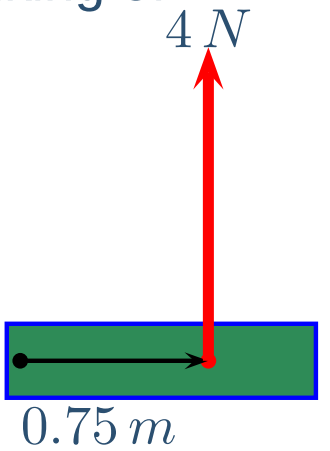

(a) 1,2,3

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(c) 2,1,3

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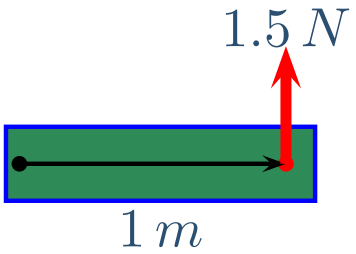

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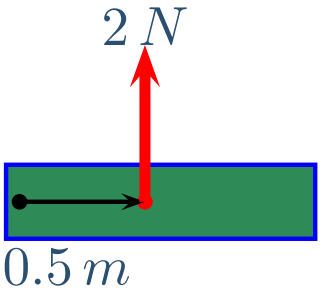

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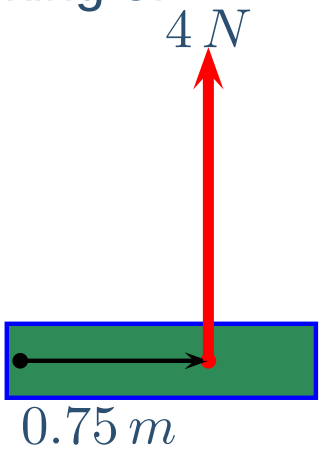

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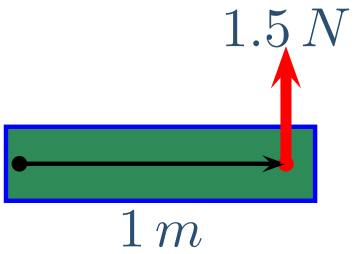

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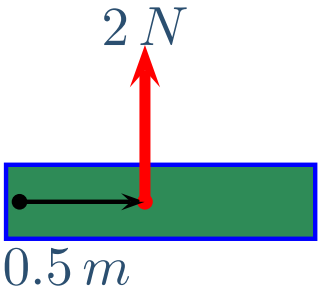

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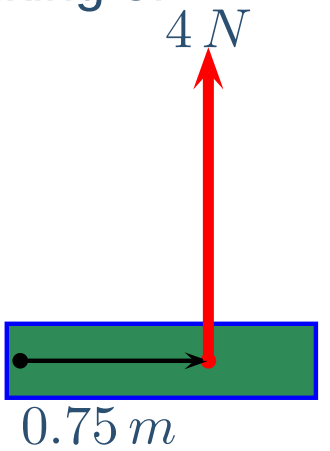

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(b) 1,3,2

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(d) 2,3,1

(e) 3,2,1

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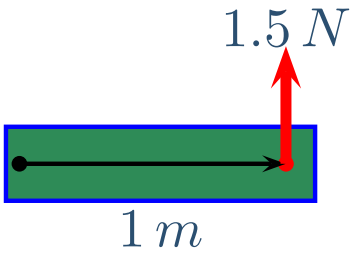
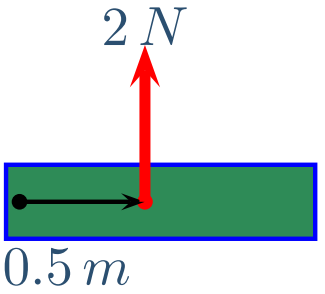


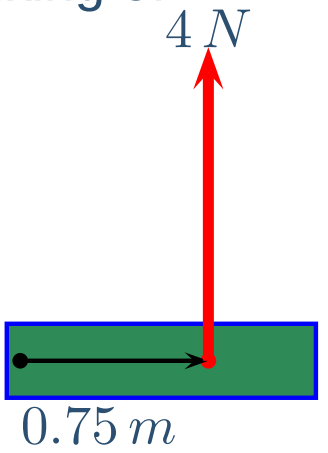
$\tau_1 = 1.5\,N \cdot m$

#2



$\tau_2 = 1\,N \cdot m$

#3



$\tau_3 = 3\,N \cdot m$

(a) 1,2,3

(b) 1,3,2

(c) 2,1,3

(d) 2,3,1

(e) 3,2,1

Torque Sign

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Positive torque $\Rightarrow$ tries to cause counter-clockwise rotation

Torque Sign

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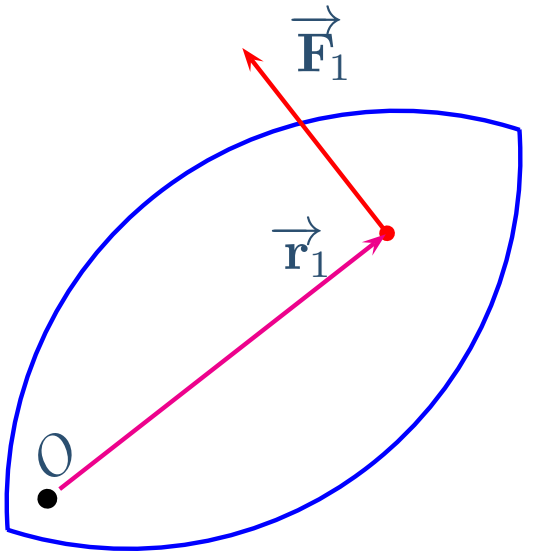

Positive torque $\Rightarrow$ tries to cause counter-clockwise rotation

τ_1 is positive

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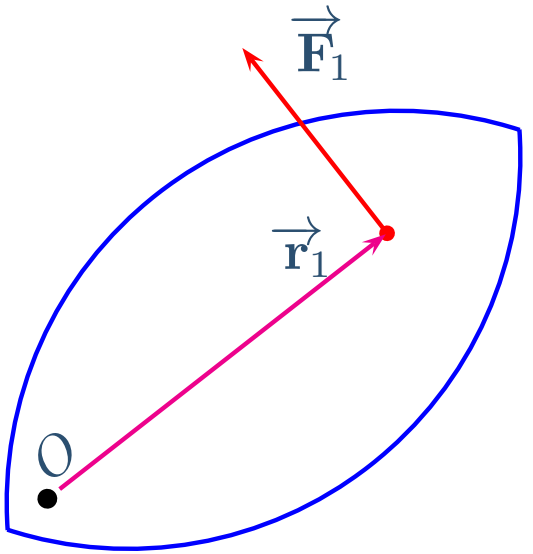

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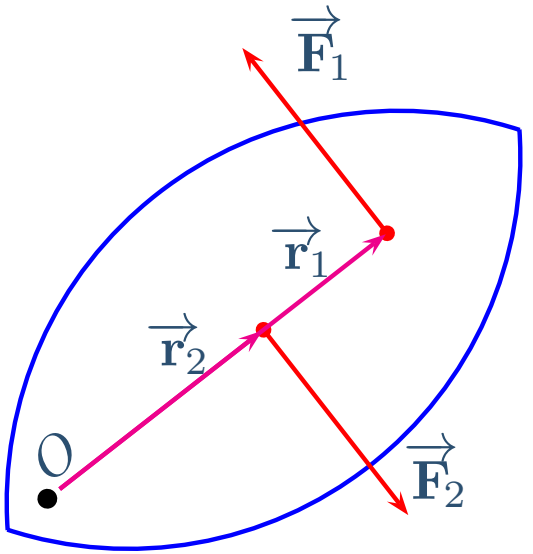


Positive torque $\Rightarrow$ tries to cause counter-clockwise rotation

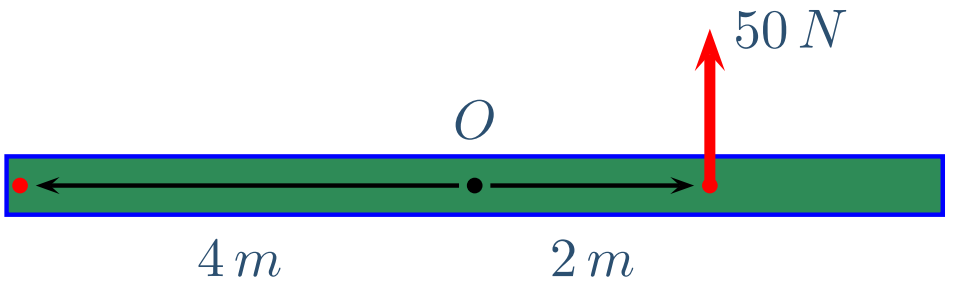
τ_1 is positive

Negative torque $\Rightarrow$ tries to cause clockwise rotation

τ_2 is negative

Torque Sign Exercise

An 8-m long beam which can rotate about its center has an upwards 50-N force applied $2\,m$ to the right of its center. What force, both magnitude and direction, must be applied $4\,m$ to the left of the center to make the net torque zero?



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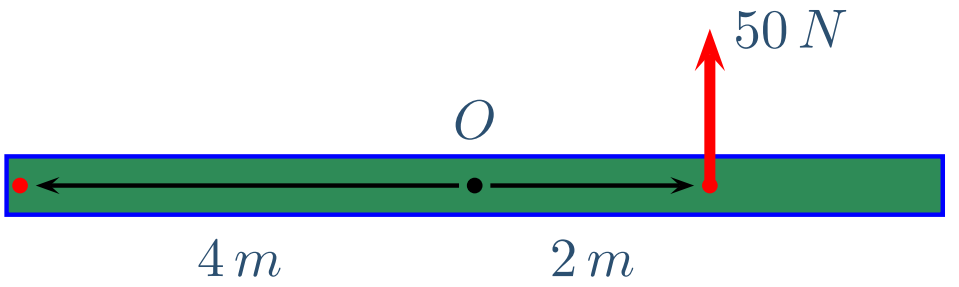

(a) $25\,N$, up

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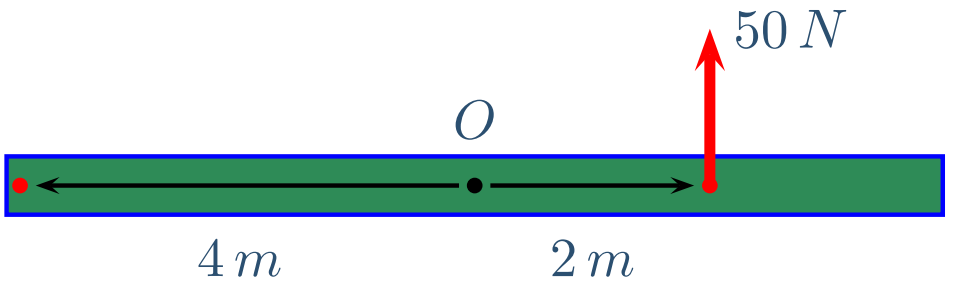

(a) $25\,N$, up

(b) $25\,N$, down

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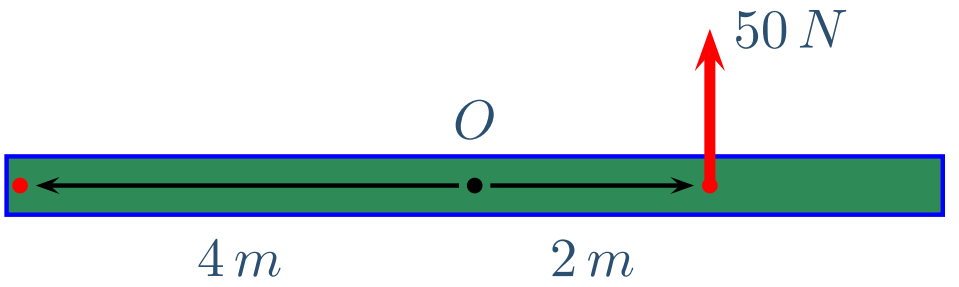

(a) $25\,N$, up

(b) $25\,N$, down

(c) $50\,N$, up

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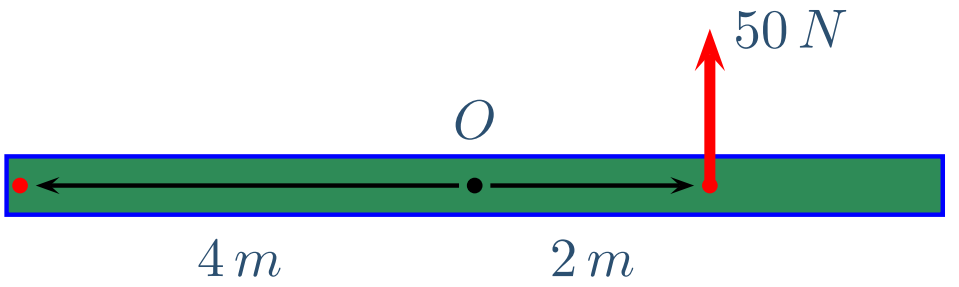

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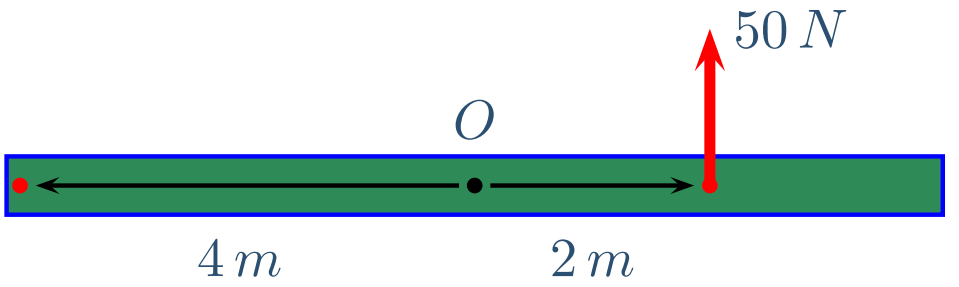

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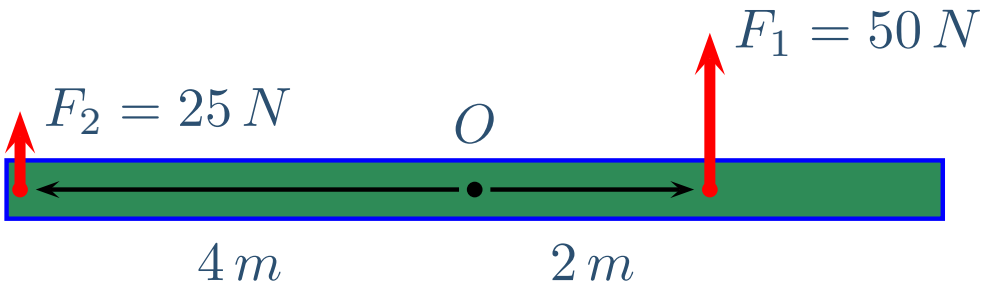

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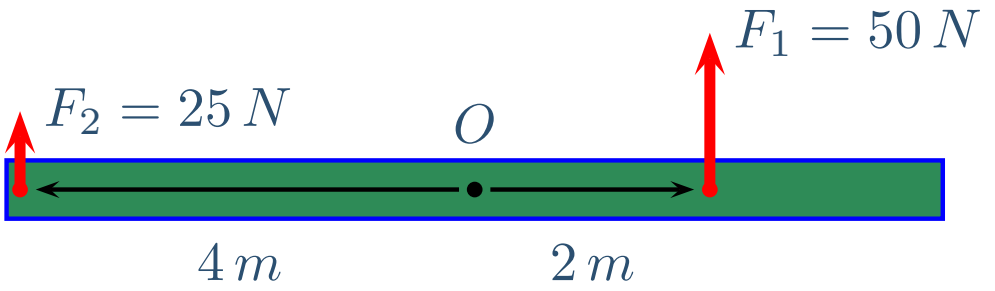

$$\tau_{net} = \tau_1 + \tau_2 = 0$$
$$\Rightarrow \tau_2 = -\tau_1$$

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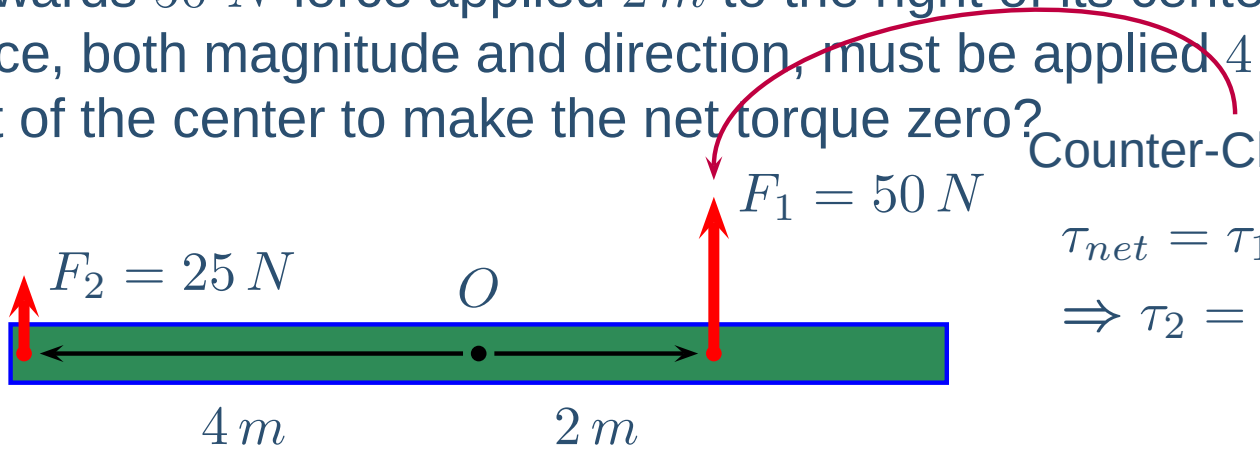

Counter-Clockwise

$$\tau_{net} = \tau_1 + \tau_2 = 0$$

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(a) $25\,N$, up

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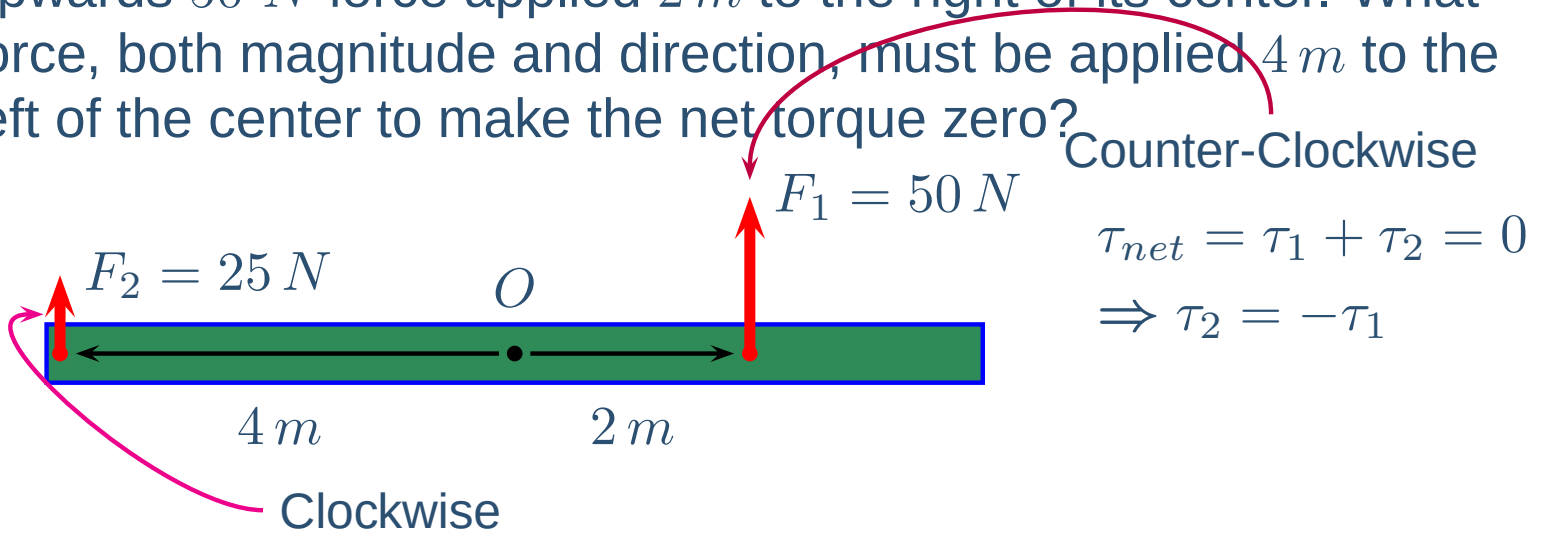

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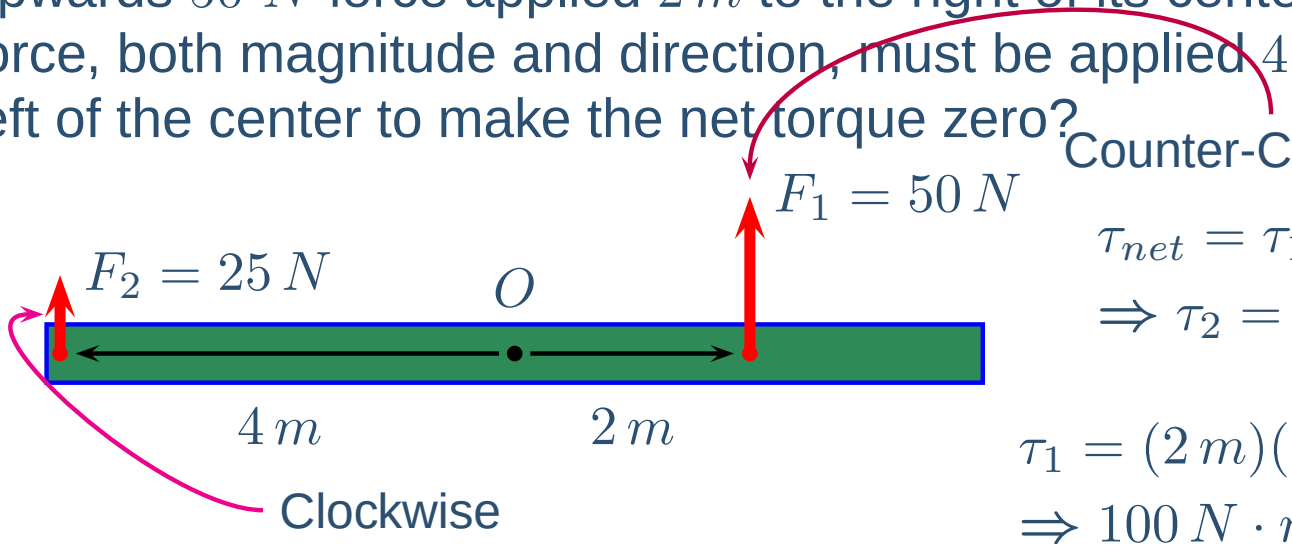

$$\tau_{net} = \tau_1 + \tau_2 = 0$$
$$\Rightarrow \tau_2 = -\tau_1$$

$$\tau_1 = (2\,m)(50\,N)$$
$$\Rightarrow 100\,N \cdot m = (4\,m)(F_2)$$

(a) $25\,N$, up

(b) $25\,N$, down

(c) $50\,N$, up

(d) $100\,N$, up

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General Torque

The direction of the force also determines the torque. When $\vec{\mathbf{F}}$ is not perpendicular to the lever arm ($\vec{\mathbf{r}}$), only the component of $\vec{\mathbf{F}}$ which is perpendicular to $\vec{\mathbf{r}}$ causes torque.

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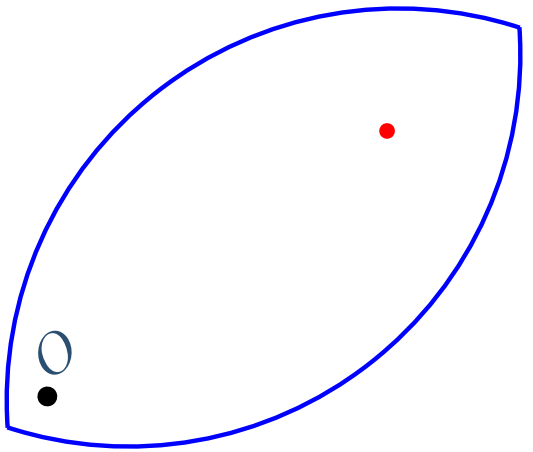

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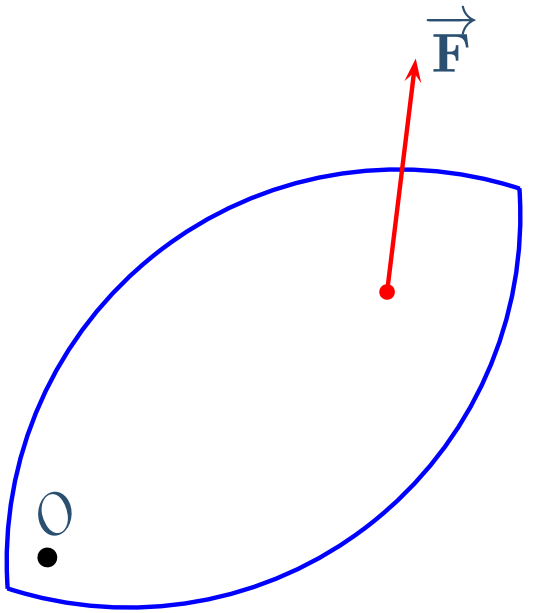

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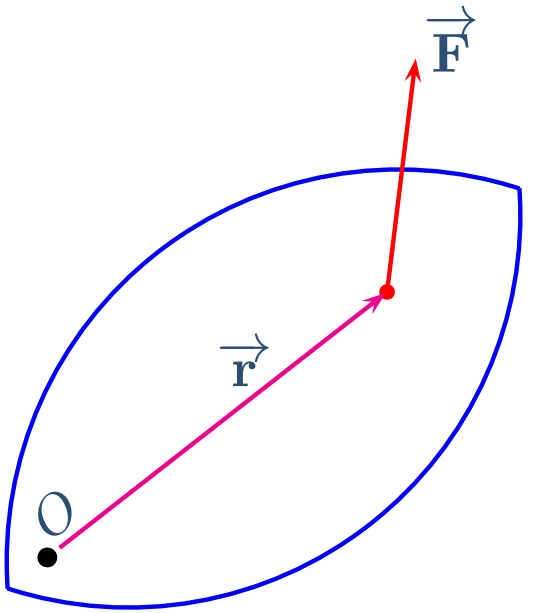

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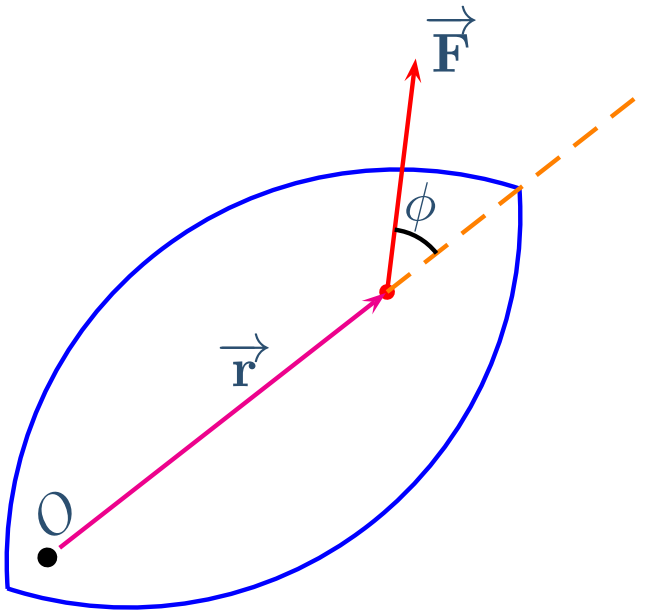

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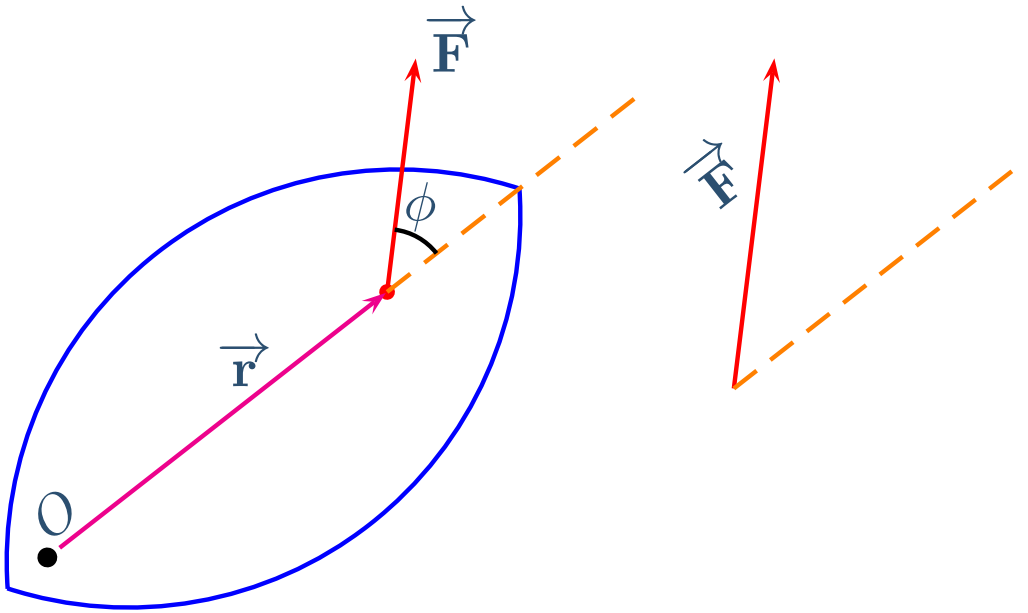

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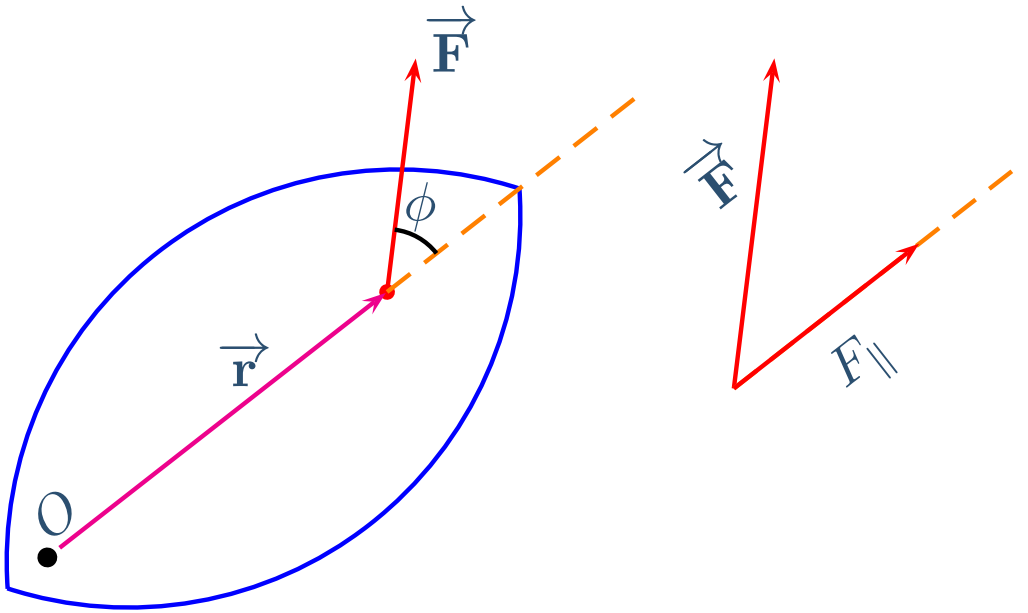

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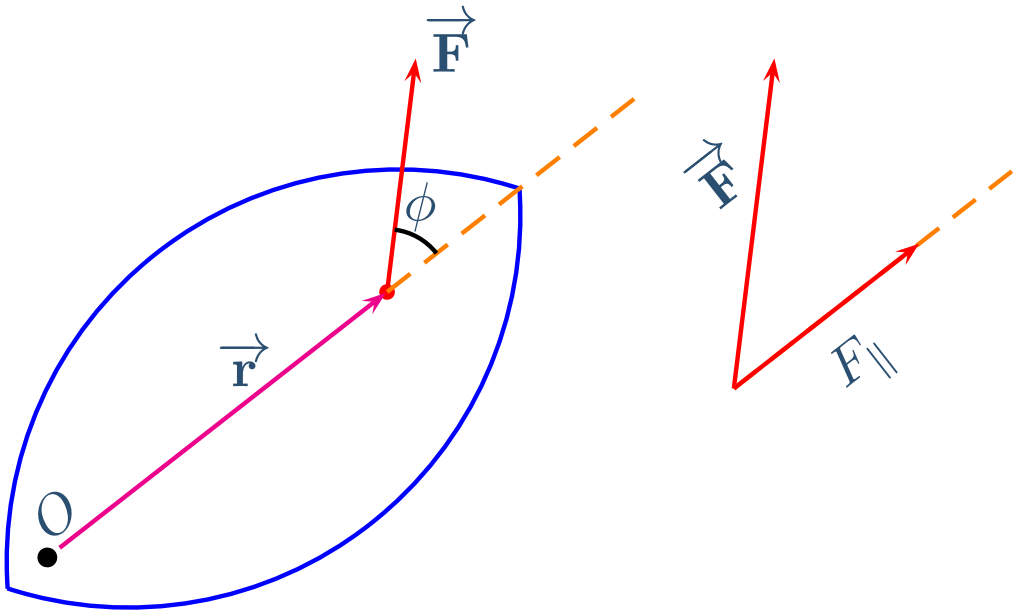

$F_{\parallel}$ - component parallel to $\vec{\mathbf{r}}$ - causes no torque

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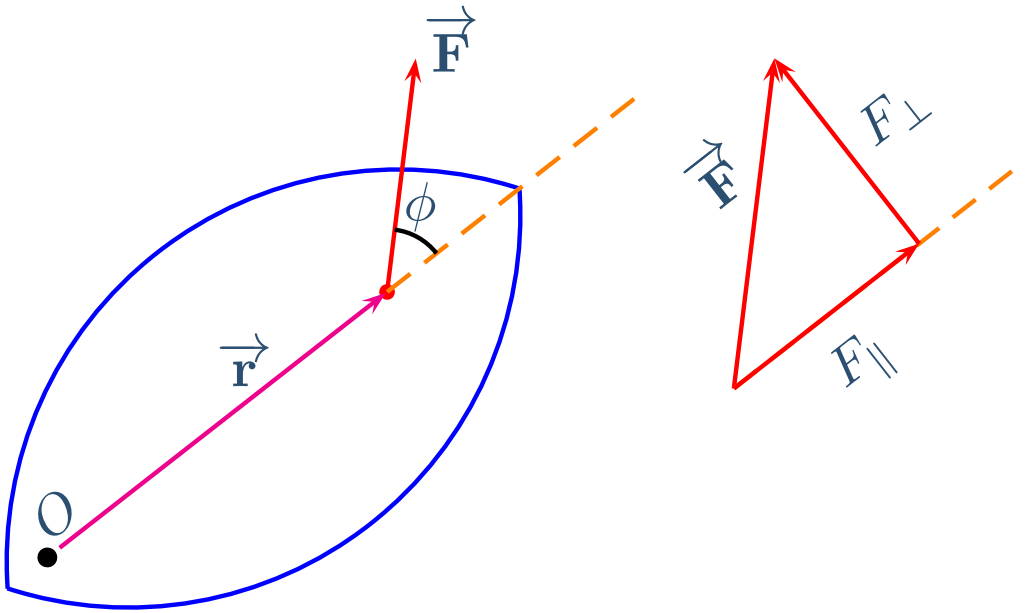

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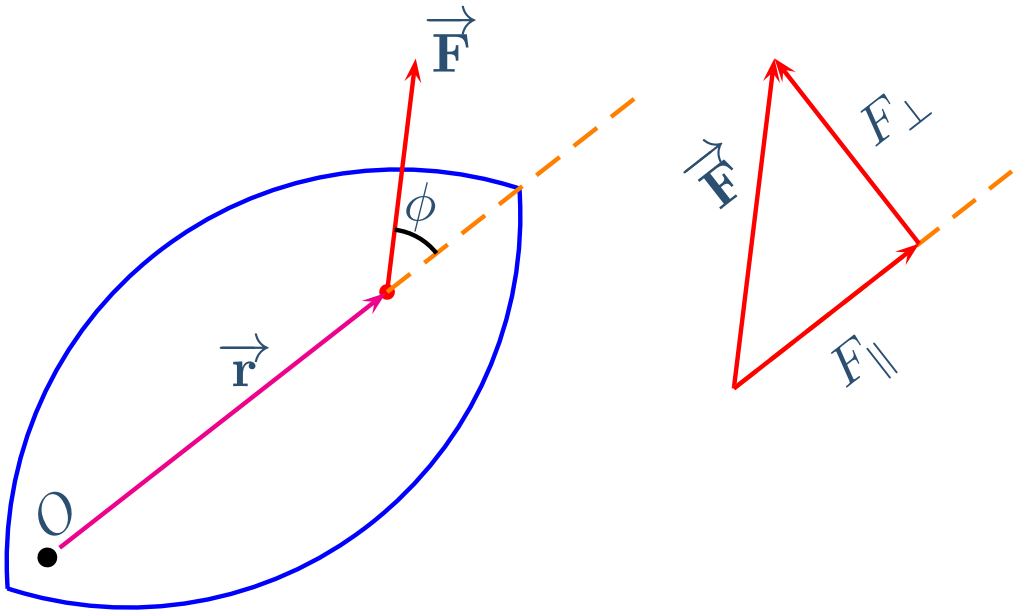

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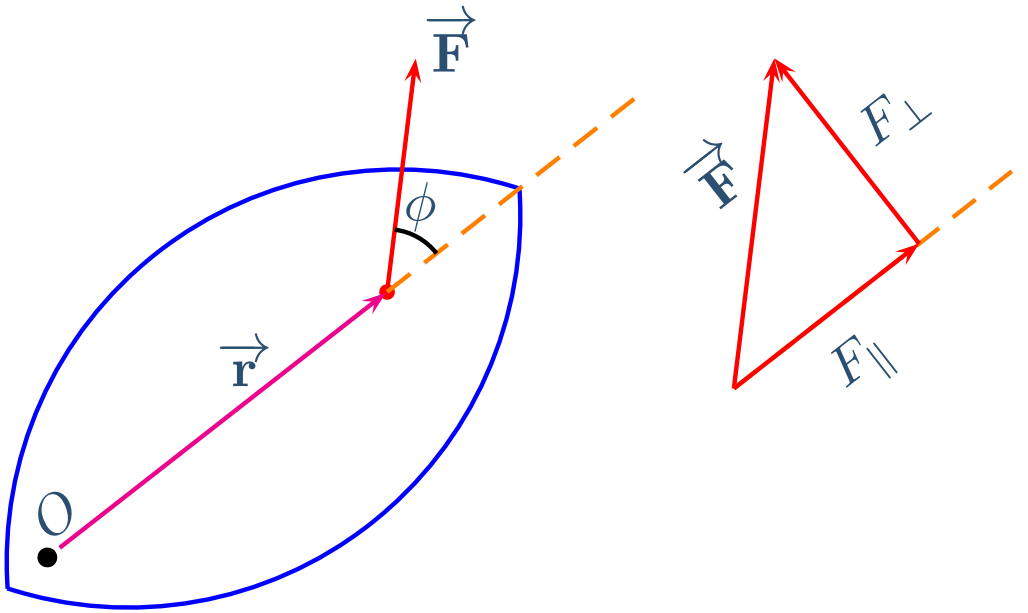

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$$\tau = rF_{\perp}$$

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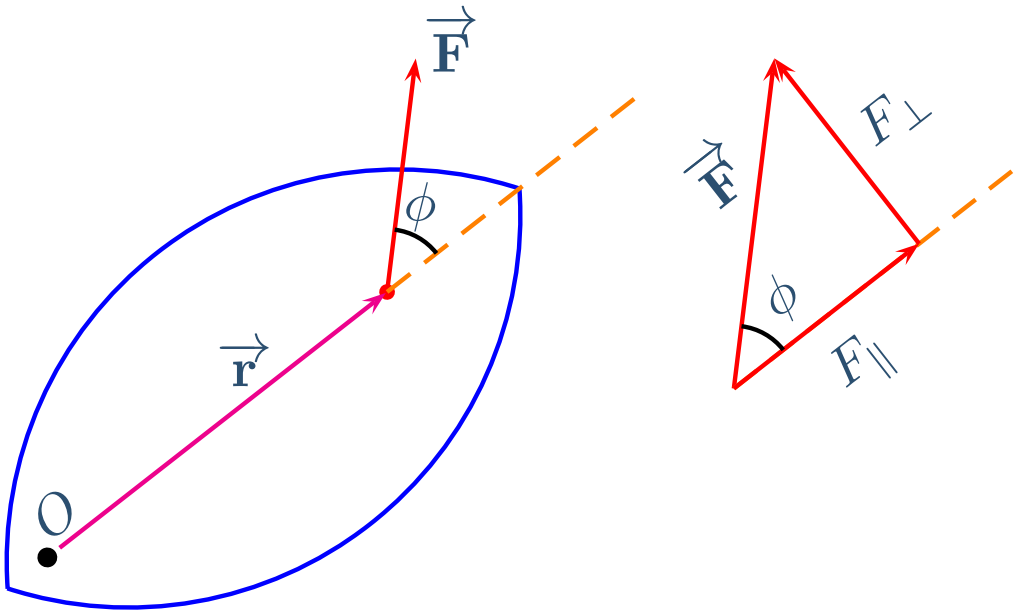

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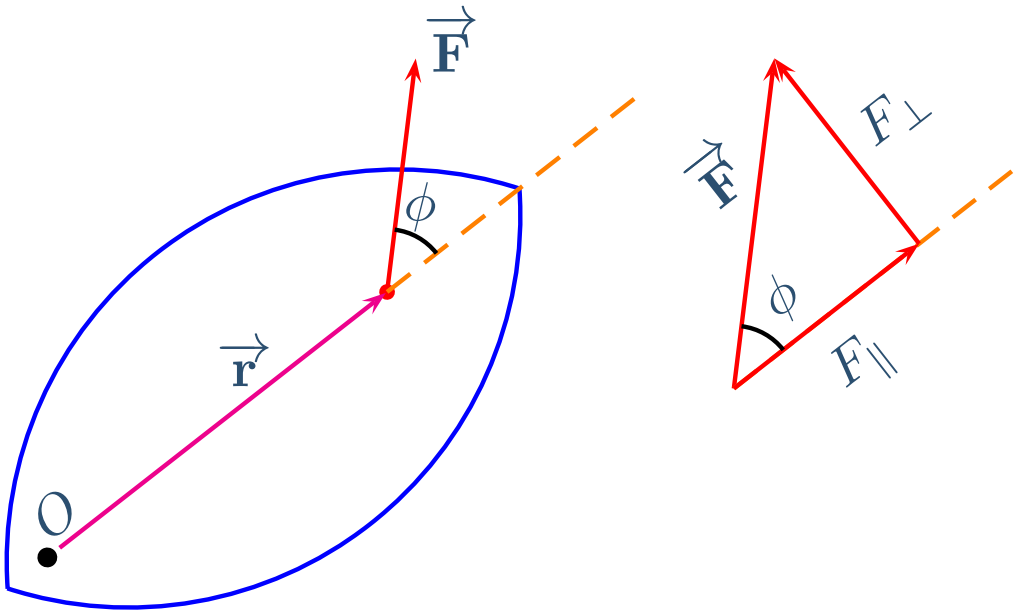

$F_{\parallel}$ - component parallel to $\vec{\mathbf{r}}$ - causes no torque

$F_{\perp}$ - component perpendicular to $\vec{\mathbf{r}}$ - causes torque

$$\tau = rF_{\perp} = rF\sin\phi$$

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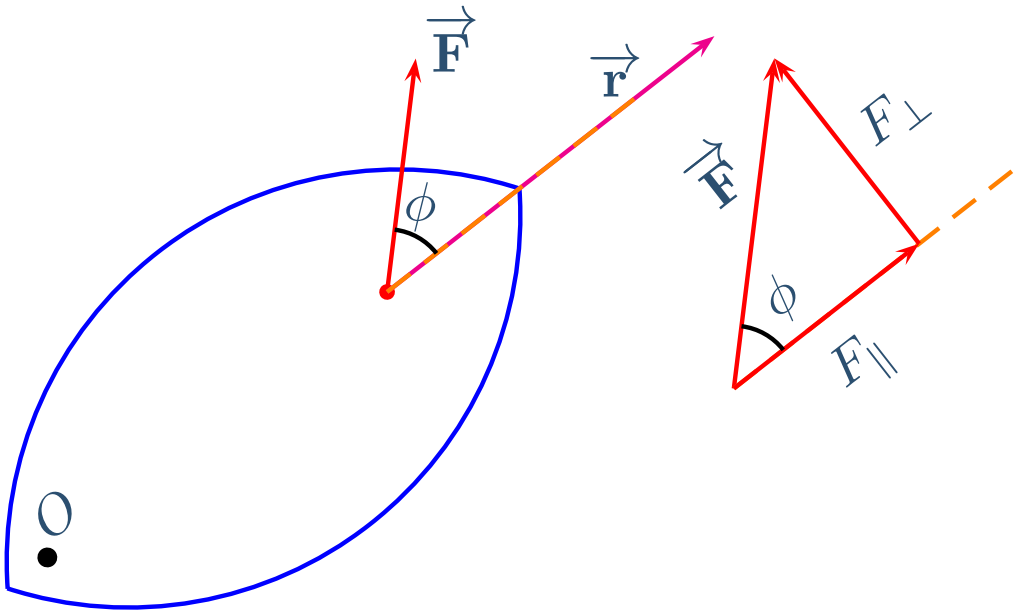

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ϕ is angle between $\vec{\mathbf{r}}$ and $\vec{\mathbf{F}}$

$$\tau = rF_{\perp} = rF\sin\phi$$